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ABSTRACT

A driver education project tested the hypothesis that measurable improvements in fleet fuel economy can be achieved by driver awareness training in fuel-efficient driving techniques and by a manifold vacuum gauge, used individually or in combination with each other. From April 1976 through December 1977 data were collected in the Las Vegas, Nevada, area from 435 light-duty fleet vehicles driven in typical highway and urban environments. More than six million test vehicle-miles were accumulated in the course of the project. The test results support the hypothesis. However, the magnitude of the improvements (four to six percent) is less than had been achieved in earlier tests conducted by others (ten to twenty percent). This difference may be attributable to the fact that motivational and performance feedback techniques were deliberately omitted from the test environment. Additionally, smaller improvements in fuel economy also appeared in the untreated control groups, suggesting that driver knowledge of the test and informal information exchange among drivers about fuel-efficient driving techniques may have influenced the results. (Information on the test site and test vehicle characteristics and description of the driver training methods and materials are appended.) (Author/CSS)

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Driver Aid and Education Test Project

Final Report

July 1978

Prepared By
Nevada Operations Office
Las Vegas, Nevada

Prepared For
U.S. Department of Energy
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and Solar Applications
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U S DEPARTMENT OF HEALTH,
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PREFACE

This test project was conducted by the staff of the Nevada Operations Office (NV), Las Vegas, Nevada, for the Department of Energy (DOE), formerly the Energy Research and Development Administration (ERDA). It is one segment of an overall DOE effort to examine hardware and techniques for the conservation of automotive petroleum fuels in existing highway vehicle fleets. The test was specifically directed to automobiles and light trucks. The DOE sponsor is the Division of Transportation Energy Conservation. Work commenced on the test project in April, 1976.

Although operational responsibility for the test project lies with NV, the technical support, cooperation, and understanding provided by the following individuals must be acknowledged: Mr. R. Husted and Dr. J. Eberhard (U.S. Department of Transportation); Dr. M. S. Huntley, Jr., Dr. C. Abernethy (U.S. Department of Transportation, Transportation Systems Center); Messrs. J. C. Hamel, B. J. Sloat and J. B. Norton (Reynolds Electric and Engineering Co., Inc.); Ms. M. Blaylock and Ms. L. Barr (EG&G).

Special recognition should be accorded to Mr. D. Malcheski (NV Project Manager) for the effort, enthusiasm, and diligence exhibited in carrying out the operational responsibility of the project. Additionally, recognition is accorded to Mr. W. Shadis (Mueller Associates, Inc.) and Ms. S. J. Soucek who coordinated and prepared the final report.

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Office of Assistant Secretary
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ABSTRACT

The Driver Aid and Education Test Project was inititated by the Department of Energy in order to test the hypothesis that measurable improvements in fleet fuel economy can be achieved by driver awareness training in fuel-efficient driving techniques and by a manifold vacuum gauge, used individually or in combination with each other. The project, conducted from April 1976, through December 1977, in the Las Vegas, Nevada area, collected data from 435 light-duty fleet vehicles driven in typical highway and urban environments. More than six million test vehicle-miles were accumulated in the course of the project.

The test results support the hypothesis stated above. However, the magnitude of the improvements (4 to 6 percent) is less than had been achieved in earlier tests conducted by others (10 to 20 percent). This difference may be attributable to the fact that motivational and performance feedback techniques were deliberately omitted from the test environment. Additionally, smaller improvements in fuel economy also appeared in the untreated control groups, suggesting that driver knowledge of the test and informal information exchange among drivers about fuel-efficient driving techniques may have influenced the results.

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EXECUTIVE SUMMARY

BACKGROUND

It has long been recognized that some drivers consistently achieve better automotive fuel economy than others, even when all other factors (vehicle size and type, driving cycle, weather, etc.) are equal. These differences can only be ascribed to the way in which the individual driver operates his vehicle. Such factors as acceleration rate, average speed, and braking and stopping techniques are known to produce significant effects on fuel economy. Tests by others have shown that by practicing known fuel-efficient driving techniques, a driver can improve his vehicle fuel economy by up to 20 percent. This project attempted to determine whether such improvements could be obtained in a representative portion of a large government fleet.

OBJECTIVES

The main project objectives were designed to answer the following questions:

- Can the use of a driver energy conservation training awareness course result in improved fuel economy for a fleet of vehicles?
- Can the use of a commercially available vacuum gauge result in improved fuel economy for a fleet of vehicles?
- Can the combined use of a driver energy conservation awareness training course and a commercially available vacuum gauge result in improved fuel economy for a fleet of vehicles?

TEST SITES AND FLEETS

A total of 435 fleet vehicles and drivers were tested in this project in urban and highway driving environments. The highway test fleet of 324 vehicles was selected at random from the total working fleet of the Nevada Test Site (NTS), a test facility operated by the Department of Energy and located 65

miles northwest of Las Vegas, Nevada. The NTS was chosen because of its fleet size, controlled access, and availability of both vehicle service and data analysis capabilities. The urban test fleet of 111 vehicles was selected from the working fleet of Clark County, Nevada, because of the predominately urban character of the driving environment, the fleet size, proximity to the NTS, and the availability of historical fuel consumption data.

METHODS

Each fleet was divided into five equal groups. One of these groups served as a control with no treatments applied. Two other groups were instrumented with two types of manifold vacuum gauges (one type for each group). One of the gauges (trade name "VacTach") utilizes a linear piston to display the relative engine vacuum. This unit contains a counter which measures the number of times the engine vacuum drops below a predetermined value (set by the manufacturer). The other gauge (trade name "Motor Minder") has a conventional needle-on-dial-type display. Numerous earlier tests by others had found that the use of vacuum gauges may result in a fuel-economy improvement if the driver operates his vehicle in a manner which maximizes the manifold vacuum. Another group was instrumented with dial-type manifold vacuum gauges and the drivers assigned to the vehicles were given a driver efficiency-awareness training course. The final group was given the same training course, but their assigned vehicles were not instrumented.

Highway fleet testing began in July 1976, with an eight-month baseline data gathering period (Phase I), during which the fuel economy of all test vehicles was recorded. The highway fleet was then divided randomly into five test groups, necessary instrumentation was mounted, instructions were given, and the fleet was subjected to an eight-month test period (Phase II). The

urban fleet testing began in July 1977, and was conducted in similar fashion, except that no baseline data period was necessary since Clark County, Nevada, had been recording fuel economy data for several years.

Two different methods were considered for analyzing the data from the Driver Aid and Education Test Project. One possible approach is to use analysis of variance to compare each group's Phase I fuel economy with its Phase II fuel economy. Although this technique does determine whether significant differences exist between Phase I and Phase II fuel economy, there is no way to assess the extent to which the test treatments caused these differences. Intervening variables such as weather, the use of air-conditioning, world events, and maturation of vehicles and drivers have a different effect on the performance of the groups during Phase I than they have during Phase II. Because the effects of these variables cannot be measured, the differences between Phase I and Phase II can only be termed observed differences and cannot be assigned exclusively to the effects of the treatments. In addition, this approach does not allow for a statistical comparison of the different treatments. Therefore, it is not possible to use this method to determine whether the difference between any two groups is significant.

Because of these limitations, an alternative method was chosen to analyze the data from this project. Analysis of variance was used to compare the performances of groups within Phase II. This is a valid comparison because an analysis of variance on the Phase I data had determined that there were no significant differences between the groups prior to treatment. This method is not jeopardized by intervening variables since it can be assumed that these variables had an equal effect on all groups because the results being compared

occurred during the same time span under the same conditions. Thus, if the results from any of the treatment groups in Phase II are significantly different from the results from any other group, these differences can be justifiably assigned to the treatment effects.

Comparing each treatment group to the control group in this manner will determine whether the test treatment has a significant effect. In addition, using the analysis of variance, it is possible to determine whether one treatment had a significantly different effect than another treatment. Therefore, this method is the only valid way to compare treatment effects.

RESULTS

The test data were aggregated using two different methods. The first method, termed "Average Group Fuel Economy" assumes that each monthly vehicle fuel economy reading (monthly miles/monthly gallons) is equally important. In essence, this method gives equal weight to each vehicle. The second method, termed "Fuel-Weighted Average Group Fuel Economy," assumes that each gallon of fuel is equally important. The results are presented, using both methods, in Tables S.1 and S.2, respectively.

The Average Group Fuel Economy data were subjected to statistical analysis in order to determine whether real (i.e., non-random) fuel economy improvements had occurred. This analysis indicated that five of the eight treatment groups experienced statistically significant improvements. Although both urban and highway segment test groups met the statistical requirements for significance, the highway segment improvements are considered more reliable due to the existence of several factors which complicated the statistical analysis performed on the urban fleet.

The Fuel-Weighted Average Group Fuel economy data indicated similar increases, but these values were not statistically analyzed.

Many of the monthly trends observed in the weighted and non-weighted data indicated that the greatest improvements in fuel economy occurred early in the treatment phases and decreased over the remainder of the phase. This effect is shown in Figure S.1. This may be evidence of a gradual loss of learned driving habits, although the effect is not uniform on all groups.

TABLE 5.1

TEST RESULTS BASED UPON AVERAGE GROUP FUEL ECONOMY

	HIGHWAY SEGMENT				URBAN SEGMENT*			
GROUP	Phase I MPG	Phase II MPG	Change: Phase II-Phase I ΔMPG (%)	Difference: Phase II-Phase II Control ΔMPG (%)	Background (Phase I) MPG	Test (Phase II) MPG	Change: Background-Test ΔMPG (%)	Difference: Test-Control ΔMPG (%)
1. (Piston-Type Vacuum Gauge)	12.81	13.34	0.53 (4.1)	0.48 (3.7)	11.10	10.7	−0.40 (−3.6)	−0.14 (−1.3)
2. (Control)	12.53	12.86	0.33 (2.6)	——	10.4	10.84	0.44 (4.2)	——
3. (Training)	12.95	13.35	0.40 (3.1)	0.49 (3.8)	10.18	10.95	0.77 (7.6)	0.11 (1.5)
4. (Training plus Dial--Type Vacuum Gauge)	13.06	13.65	0.59 (4.5)	0.79 (6.1)	10.14	10.68	0.54 (5.3)	−0.16 (−1.5)
5. (Dial-Type Vacuum Gauge)	12.72	13.24	0.52 (4.0)	0.38 (3.0)	10.96	11.50	0.54 (4.9)	0.66 (6.1)
All	12.81	13.29	0.48 (3.7)	0.43 (3.3)	10.56	10.93	0.37 (3.5)	0.09 (0.8)

*The statistical significance of the urban results is qualified.
See Section 5.1.1.

TABLE S.2

TEST RESULTS BASED UPON FUEL-WEIGHTED AVERAGE GROUP FUEL ECONOMY

	HIGHWAY SEGMENT				URBAN SEGMENT			
GROUP	Phase I MPG	Phase II MPG	Change: Phase II-Phase I Δ MPG (%)	Difference: Phase II-Phase II Control Δ MPG (%)	Background (Phase I) MPG	Test (Phase II) MPG	Change: Background-Test Δ MPG (%)	Difference: Test-Control Δ MPG (%)
1. (Piston-Type Vacuum Gauge)	12.73	12.71	−0.02 (−0.2)	0 (0)	N/A*	10.49	N/A	−0.72 (−6.4)
2. (Control)	12.51	12.71	0.20 (1.6)	——	N/A	11.21	N/A	——
3. (Training)	12.84	12.98	0.14 (1.1)	0.27 (2.1)	N/A	10.97	N/A	−0.24 (−2.1)
4. (Training plus Dial-Type Vacuum Gauge)	12.67	13.37	0.70 (5.5)	0.66 (5.2)	N/A	10.82	N/A	−0.39 (−3.5)
5. (Dial-Type Vacuum Gauge)	12.89	13.28	0.39 (3.0)	0.57 (4.5)	N/A	11.94	N/A	0.73 (6.5)
All	12.72	13.00	0.28 (2.2)	0.23 (2.3)	N/A	11.09	N/A	−0.12 (−1.1)

*Not available.

Finally, each of the highway fleet drivers was requested to respond to a questionnaire immediately upon completion of the project. The results of this questionnaire indicate an overall positive response to the Driver Aid and Education Test Project. This is most evident in the assessments of the driver training course. The majority of course participants indicated that the training course was a valuable source of fuel-conservation driving techniques and a positive influence on personal driving habits.

Response to the vacuum gauge driver aids varied according to the type of vacuum gauge used in the test. The dial-type device was judged to be an effective aid to fuel-efficient driving; the piston-type gauge received a generally negative response. This difference appears to result from a combination of frequent malfunction and difficulties in reading the gauge which occurred with the piston-type device. These problems were not encountered by those participants who used the dial-type vacuum gauge.

OBSERVATIONS AND CONCLUSIONS

The following observations and conclusions, listed in order of importance, are based upon analysis of the results obtained from the Driver Aid and Education Test Project.

- The results obtained in this test project provide support for the hypothesis that measurable and statistically significant increases in fuel economy can be achieved by the use of a driver energy efficiency awareness training course or a manifold vacuum gauge, or by use of the training in conjunction with the manifold vacuum gauge.
- Review of the monthly trends in group fuel economy indicate an apparent degradation of motivation or of behaviors learned in the training course for most of the treatment groups.

- Comparisons of the dial-type and the piston-type vacuum gauges made using the Average Group Fuel Economy method of data aggregation show that both gauges achieved similar, significant increases in fuel economy in the highway segment of the test. The urban segment results, while of less statistical importance, indicate a clear advantage of the dial-type as compared to the piston-type gauge. Non-statistical comparisons using the fuel-weighted method of data aggregation also indicate a strong advantage for the dial-type gauge. However, statistical analysis indicates that it is not possible to reject the hypothesis that the two gauges tested were equally effective.
- The results of the driver questionnaires indicate that drivers who used the dial-type gauge gave a positive overall response to the gauge about twice as often as drivers who had used the piston-type.

RECOMMENDATIONS

Based upon the results of this test project, the following recommendations are offered:

GENERAL RECOMMENDATIONS

- The immediate installation of vacuum gauges alone on additional government vehicles is not recommended at this time. Use of vacuum gauges should be considered only in conjunction with a formal program to motivate and train government drivers in driver energy conservation awareness techniques, and the gauges should only be used as a driver training aid.
- It is recommended that the Department of Energy provide continued support for research in the area of fuel-efficient driving techniques. Specifically, questions of optimum acceleration rate, braking, turning,

stopping, hill climbing and hill descending should be investigated to determine the optimum techniques for use in driver energy awareness training curricula. This type of research activity has two-fold importance: the research can provide useful information for energy conservation and policy decisions using existing technology, and the interest in fuel economy exemplified by the projects will provide an example of energy conservation activities which could be pursued by other vehicle fleet operators.

- o Further analysis of the data collected during this test project is recommended, specifically in the areas of statistical methods, driver characteristics, vehicle characteristics, the Hawthorne effect, correlation of fuel economy with driver characteristics and job assignments, and other parameters that may assist in explaining data inconsistencies or observed anomalies.
- o It is recommended that the Federal Government consider institution of the requirement that all applicants for federal driver's licenses (both government employees and government contractors) complete training in driver energy conservation awareness prior to licensure.
- o It is recommended that a teaching textbook be prepared for vehicle fleet operators. This text should also be suitable for use by the public school system and the general motoring public.
- o It is recommended that further research in human factors be initiated in order to develop more effective methods of providing audio/visual/tactile feedback to the vehicle driver, facilitating fuel-efficient driving behaviors.

SPECIFIC RECOMMENDATIONS

- It is recommended that the Driver Energy Conservation Awareness Training be continued, and expanded to include all Government-licensed drivers at the Nevada Test Site, and the Nevada Operations Office in Las Vegas, Nevada.
- It is recommended that all light-duty vehicles at the Nevada Test Site be instrumented with dial-type vacuum gauges, but only in conjunction with driver energy conservation awareness training.
- It is recommended that fuel and mileage records be kept on all light-duty vehicles at the Nevada Test Site, in order to monitor the effects of driver training.
- It is recommended that driver energy conservation awareness training methods be further refined and modified to suit the specific driving environment and types of vehicles used at the Nevada Test Site.

1.0 BACKGROUND

1.1 HISTORICAL BACKGROUND

Historically, there has been little public interest in improving automotive fuel economy. In the United States, the real price of motor fuels (defined as the number of hours worked to pay for a gallon of fuel, tax included) has shown a consistent decrease from the advent of the automobile until about 1970. Between 1919 and 1970, the real price of gasoline declined by 70 percent. This fiscal environment was not conducive to petroleum fuel conservation.

The rise in real cost of motor fuels which resulted from the oil embargo of 1973-1974 changed this environment, bringing the quest for improved fuel economy to the forefront. Extensive research was undertaken to improve vehicle technology, with the goal of increasing fuel economy. However, it was soon recognized that while hardware improvements can have a salutary national effect, the time required for implementing significant national hardware changeover is measured in 5 to 15 year intervals. Secondly, such improvements are often capital-intensive, further slowing implementation of new hardware technology.

In addition, fuel economy research reveals that even when all other variables are controlled, significant variations in fuel economy exist which can only be ascribed to the driver. It is not unusual to find a variation of 30 to 50 percent in fuel economy among a group of non-professional drivers operating under identical and controlled test conditions.

In this light, driver energy conservation awareness training appeared as a promising technique for increasing fuel economy. Numerous limited test programs indicated that appropriate educational techniques could improve the fuel economy of a group of average drivers by 10 to 20 percent. If these

results were applicable to even 10 percent of the national highway fleet (autos, trucks, buses, etc.), a reduction of 1.3 to 2.1 billion gallons per year in demand for petroleum fuels could be realized. If this resulted in an equivalent reduction in imported petroleum demand, a 400 to 800 million dollar per year reduction in the balance of payments deficit could occur.

However, many of these early tests were conducted under circumstances which make their reliability and validity questionable. Many of the tests were undertaken by individuals or private companies who were under no obligation to publicize their findings. It is possible, indeed probable, that test results which demonstrated small improvements or no improvement were not publicized. In addition, most of these tests were conducted over a short time period using a small number of volunteer participants (often less than 10 or 20). Frequently an instructor supplied strong extrinsic motivation by being seated next to the student throughout the test. Finally, some of these tests were conducted by organizations or individuals with direct financial interest in the results.

While these qualifications do not necessarily invalidate the early test results, more objective data collection and analysis are required to justify a national driver education program. Therefore, the Transportation Energy Conservation Division (TEC) of the Department of Energy (DOE) decided to conduct a test program in order to evaluate the effectiveness of driver energy conservation awareness training on Government fleet drivers. Positive results obtained in this program would enhance the role undertaken by the Government in the field of driver energy conservation awareness training.

1.2 PROJECT BACKGROUND

In March of 1976, it was decided that a test project should be conducted to evaluate the effectiveness of vacuum gauges and/or driver energy conservation training techniques.

The Nevada Test Site (NTS) fleet was chosen for this project on the basis of the following factors: (a) the NTS fleet was composed of more than 2000 light-duty vehicles; (b) the average driving cycle was typical of suburban/highway travel; (c) the fuel input to each vehicle could be carefully monitored; (d) the facility had the capable personnel and equipment needed to conduct the test; and (e) the NTS management expressed a positive attitude toward the project. No other fleet within DOE or any other Federal Agency was judged equally qualified for the purposes of this test. The test began in April 1976, but shortly after test initiation it was determined that the test should include an urban driving segment in order to make it more representative of fleet operations. The automotive fleet of Clark County, Nevada, numbering almost 1500 vehicles and used almost exclusively in urban Las Vegas, Nevada, was chosen for this purpose. Many factors similar to those considered in the selection of the NTS fleet prevailed in the selection of the Clark County fleet.

This combination of the NTS fleet and the Clark County fleet provided driving environments typical of those encountered by most fleet drivers in the United States.

Two types of driver aid devices were chosen for the project: a manifold vacuum gauge with a linear piston indicator and a low-vacuum event counter; and a manifold vacuum gauge with the more conventional dial indicator display. These manifold vacuum gauges were chosen for this project because of their

relatively low cost, wide availability (both for the project and for the mass market), and simplicity of installation and use.

2.0 OBJECTIVES

2.1 PRIMARY OBJECTIVES

The Driver Aid and Education Test Project was designed to achieve three primary objectives:

1. To assess the extent to which use of a manifold vacuum gauge driver aid device, as available in the consumer market, could improve fuel economy:
2. To assess the extent to which participation in a driver awareness training course could improve fuel economy;
3. To assess the extent to which use of a vacuum gauge driver aid device used in combination with driver awareness training could improve fuel economy.

The following discussion focuses on the rationales involved in formulating these primary project objectives.

Professional drivers have successfully used manifold vacuum gauges as an aid to maximizing fuel economy performance in tests such as the Mobilgas Economy Runs. Although these devices have been found to be useful in professional fuel economy driving, there is no adequate evidence to show that an average driver can achieve improved fuel economy simply by using a vacuum gauge as purchased in the consumer market. Therefore, the first test objective was to assess the extent to which an average driver, with no specific training other than instructions which might be supplied by the manufacturer, could improve his fuel economy by the use of a vacuum gauge.

A second approach to improved fuel economy has been through training in fuel-efficient driving techniques. While it has been shown in various fuel economy tests that certain driving techniques result in increased fuel economy,

neither the driving public nor drivers of most government and industrial vehicle fleets have received systematic training in fuel-efficient driving techniques. Therefore, the second test objective was to assess the extent to which formal training in proven fuel-efficient driving techniques could improve the fuel economy achieved by a typical government fleet driver.

Since effective fuel-economy driving appears to be a learned behavior requiring concentration, interest in practicing new techniques, and a desire to improve driving abilities, it was assumed that a driver aid device might provide the driver with a positive reinforcement of the techniques learned in a training course. By providing the driver with immediate feedback on his technique, the device could contribute to reinforcing fuel-efficient driving habits, thus enhancing the development of new, fuel-efficient driving behaviors. The third objective was thus to assess the extent to which a driver aid device, used in combination with a driver awareness training course, would result in improved fuel economy. A corollary to this investigation was to compare the fuel economy obtained when using either a vacuum gauge alone or driver training alone.

These three objectives constitute the primary purposes of the Driver Aid and Education Test Project, and the major portion of this report is devoted to discussion of the test findings as they relate to these primary objectives. A number of secondary objectives were also considered for the project, with the constraint that they would be investigated only if project timing permitted further elaboration of the test findings. While there are data available which pertain to the secondary objectives (see Appendix F), most of these are not discussed in this report.

Early in the project, it was decided that one specific vacuum gauge, the linear-piston type, should be tested. This gauge, sold under the commercial name "VacTach," incorporates a counting device to measure low-vacuum events. The first secondary objective of the project concerns this particular device.

2.2 SECONDARY OBJECTIVES

A. To examine the linear vacuum gauge in terms of:
   1. Fuel efficiency ratio (FER)* vs. fuel economy;
   2. Degradation curve for FER.

B. To develop fuel economy degradation curves for:
   1. Tune-ups;
   2. Driver awareness training;
   3. Vacuum gauge utilization;
   4. Driver awareness training plus vacuum gauge utilization.

C. To collect comments from drivers regarding
   1. Vacuum gauge driver aids:
      a. with driver awareness training
      b. without driver awareness training;
   2. Driver awareness training.

D. To assess the effectiveness of the driver aid in alerting the driver to engine/vehicle problems.

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*See Glossary

3.0 TEST METHODS AND PROCEDURES

3.1 TEST PLAN

A detailed plan describing objectives, test methods, analytical procedures and techniques, and necessary data was formulated for the test. Two test segments were conducted in order to represent both highway and urban driving conditions. Four different treatment groups and a control group within each segment were necessary in order to generate the data required to achieve the test objectives. Thus, both the urban and the highway test fleets were divided into the following groups:

Group 1: All vehicles in this group were equipped with a linear piston-type manifold vacuum gauge.

Group 2: Control group (no treatment)

Group 3: All drivers in this group completed training in fuel-efficient driving techniques.

Group 4: All vehicles in this group were equipped with a dial-type manifold vacuum gauge and the drivers completed training in fuel-efficient driving techniques.

Group 5: All vehicles in this group were equipped with a dial-type manifold vacuum gauge.

These five groups were necessary in order to determine effects on fuel economy resulting from the use of vacuum gauges and driver training, separately and in combination.

Figure 3.1 provides a summary description of test plan implementation.

FIGURE 3-1

TEST PLAN IMPLEMENTATION

Segment	Pre-Phase I	Phase I	Phase II
Highway (NTS)	• Test of Data Collection System (30 vehicles)	• Vehicle Preparation • Collection of Fuel Consumption Data	• Installation of Vacuum Gauges • Driver Training Course Conducted • Data Collection • Data Analysis
Urban (Clark County)	• not required*	• not required*	• Vehicle Preparation • Installation of Vacuum Gauges • Data Collection • Data Analysis

*Fuel economy data were available from Clark County records.

Highway Test Segment

The highway test segment was conducted in three phases: Pre-Phase I, Phase I, and Phase II.

Pre-Phase I included a test of the data collection system to be used for the entire test. Checks were made to insure that data would be received in a timely manner and that the analyses could proceed according to the test plan. This phase lasted approximately two months and utilized a sample of 30 vehicles.

Phase I included classification of the NTS vehicles chosen for the test sample, mechanical preparation of these vehicles, and collection of baseline fuel consumption data for each driver/vehicle combination. The baseline fuel consumption data collected in Phase I would later be used for comparison with the test data collected in Phase II.

Phase II of the highway segment included installation of the vacuum gauges, presentation of the driver awareness training course, collection of fuel economy data, and data analysis.

The highway test segment extended over a 16-month period.

Urban Test Segment

The urban segment test manager (Clark County, Nevada) had previously collected baseline fuel consumption data for each of the driver/vehicle combinations in this fleet. Therefore, Pre-Phase I and Phase I procedures were not required and the urban test segment lasted only eight months.

Phase II of the urban test segment included installation of the vacuum gauges, presentation of the driver awareness training course, collection of fuel economy data, and data analysis.

3.2 IMPLEMENTATION OF THE TEST PLAN

3.2.1 Vehicle Preparation

All vehicles included in the test were classified according to size and weight, transmission type, and air conditioning option. Each test vehicle was clearly identified to indicate participation in the test. All analyses and documentation produced reference the vehicle license number, which can be matched to the vehicle, the driver, and the organization with which the driver was associated.

A locking gas cap was installed in each test vehicle. The key to the gas cap was controlled by the driver assigned to that vehicle.

All highway segment vehicles were tuned at the beginning of each test phase. In most instances, manufacturers' specifications were followed. However, some of the older test vehicles were not designed for operation with no-lead gasoline (the only type available at the site). Thus, it was necessary to modify manufacturers' specifications (primarily spark timing) for some of these vehicles in order to insure proper operation. Such modifications are a matter of standard maintenance policy and were not instituted solely for this test. The modified specifications are permanently recorded for reference at the shop facility. In addition, vehicle spark plugs, points, and condensers were replaced, timing and idling speeds were checked and corrected as necessary, and each vehicle was tested on a dynamometer to ascertain that no other mechanical problems existed. All urban test segment vehicles were similarly tuned on an as-needed basis according to manufacturers' recommended mileage/time intervals.

Odometer error for each vehicle was determined and recorded for use in analysis. These procedures were carried out on the highway segment vehicles at

the beginning of Phase I and also at the beginning of Phase II. Urban segment vehicles were subjected to these procedures only at the beginning of Phase II, since there was no Phase I for the urban fleet.

Installation of the vacuum gauges in selected vehicles constituted the final step in preparing the vehicles for testing.

3.2.2 Driver Awareness Training

Highway Segment

The highway segment training was conducted in two stages: two hours of formal classroom instruction, followed (one to two weeks later) by two hours of practice driving in an instrumented training vehicle.

The classroom instruction format consisted of a lecture incorporating visual aids, and two films presenting various fuel-efficient driving techniques. The average class size was 18 students. The students were encouraged to practice the fuel-economy techniques taught in the classroom before they returned to drive the instrumented training vehicle.

Figure C-4 (Appendix C) illustrates the driving route within the NTS complex which was selected to demonstrate various driving techniques. The student was asked to drive the route initially using his normal driving techniques. Fuel usage, time elapsed, and distance traveled were recorded. The student was then directed to drive the route in a fuel-efficient mode, with the instructor coaching on the various driving techniques at the points along the route where these techniques could be utilized. Again, fuel usage, elapsed time, and distance traveled were recorded. The results of this experiment are described in Appendix C.

Urban Segment

The driver energy conservation awareness training used in the urban

segment was similar to the highway segment training, with the following variations:

a. The course was conducted in a drive-class-drive format and completed in one day. Students were directed to drive normally prior to the classroom instruction. The economy driving runs were conducted immediately after the classroom training.

b. The driver awareness training course was reduced to three hours by eliminating one of the movies and some of the lecture material.

c. The class size averaged nine students per session.

d. The driving portions were conducted in an urban driving environment.

Two foremen from the REECO Fleet Operations Department were recruited to serve as on-the-road driving instructors. These individuals received an intensive four day course which included free use of the instrumented vehicles. The use of volunteers, rather than professional instructors, was carefully considered early in the project. It was felt that instructors from the peer group would be more effective than outsiders, particularly in view of the limited time available for administering the course and developing the presentation technique.

Driver Questionnaires

A driver questionnaire was issued to each highway segment test participant upon completion of the project. The results of the questionnaire are discussed in Section 5.2.

3.2.3 Data Collection

Data were collected through the use of log books maintained by each driver and by the attendants at the three service stations located on the test site. Each log book recorded the following information: vehicle identification number, date of

fill-up, gallons per fill-up, and odometer reading. All fuel dispensing pumps used in the project were calibrated to one percent (1%) accuracy before the beginning of each test phase. A sample form of each log sheet is contained in Appendix A.

The recorded data were submitted to the analysis group on a monthly basis.

3.3 TEST FACILITY SELECTION

The Nevada Test Site (a facility of the Department of Energy located approximately 65 miles northwest of Las Vegas, Nevada), was chosen as the location of the highway test segment. The NTS was used in this project for the following reasons:

1. It possessed a large fleet (approximately 2,000) of light-duty vehicles (compact automobiles, intermediate automobiles, and pickup trucks) from which a satisfactory test sample could be drawn.
2. The test vehicles would be operated in a controlled area (almost exclusively within the 1,400 square mile facility), making it possible to monitor fuel use, driving cycles, and vehicle state-of-tune.
3. The site has a large technical staff, on-site auto repair and service facilities, computer facilities, and personnel capable of analyzing the test results.
4. The majority of vehicles on site were assigned to only one driver. This factor simplified the task of associating driver treatment with vehicle performance.
5. The test site management expressed a substantial interest in the program and agreed to support it as a priority project.

The Clark County fleet was chosen for the urban test segment for the following reasons:

1. The average driving cycle (downtown Las Vegas, Nevada) is typical of urban travel in this geographic region.
2. The County facility is located near the DOE Nevada Operations Office and could be closely monitored by the DOE project manager.
3. The fleet has nearly 1,500 vehicles from which to draw the test sample.

Other potential urban and highway test sites were considered, but none offered the desired combination of fleet size, driving cycle, management interest, and analysis capabilities.

3.4 DRIVER AID SELECTION

A driver aid is a mechanical or electronic device which can provide vehicle performance or other fuel economy information without directly influencing any vehicle system. Speedometers, odometers, and tachometers are examples of Original Equipment Manufacture (OEM) driver aids typically found on automobiles and other light-duty vehicles.

One of the purposes of the Driver Aid and Education Test Project was to assess changes in vehicle fuel economy resulting from vacuum gauge driver aids. Final selection of the particular manifold vacuum gauges to be used in this test was based upon the following criteria:

Screening Criteria

1. Availability for project (January, 1977);
2. Total cost (parts and installation) under $50;
3. Compatibility with test vehicles.

Quality and Performance Criteria

1. Presentation of a clear visible and/or audible signal of efficient/inefficient driving techniques;

2. Relative ease of installation by available shop personnel;

3. Product warranty of at least 90 days.

Three types of manifold vacuum gauges were commercially available at the time of the test: the circular dial type (Figure 3.2), the indicator light, and the linear piston type (Figure 3.3).

The circular dial type of device instantaneously indicates the intake manifold vacuum by a pointer on the dial face. These devices display manifold vacuum in relative terms (good, fair, poor).

The indicator light type of vacuum gauge informs the driver of vacuum level through one or more indicator lights, which are designed to activate at pre-set vacuum levels.

The third type of vacuum gauge is a linear piston with low-vacuum event counter. As engine vacuum increases, the piston is gradually pulled into its housing, displaying a different color on the piston at various vacuum levels. A counter on the end of the piston housing records low-vacuum events. According to the manufacturer of this type of gauge, there is a relationship between fuel economy and the number of low-vacuum events which occur.

The particular linear piston-type vacuum gauge to be used in the test had been previously specified (see Section 2.1). The device chosen was the VacTach, a linear piston gauge with a low-vacuum event counter, manufactured by C&E Enterprises, Inc.

Using the pre-determined selection criteria outlined above, a review of available vacuum devices was undertaken and a dial-type gauge was also chosen for the test. This was the Motor Minder, a dial-type vacuum gauge manufactured by Stewart-Warner, Inc. Throughout the remainder of this report, these devices are referred to by their generic names.

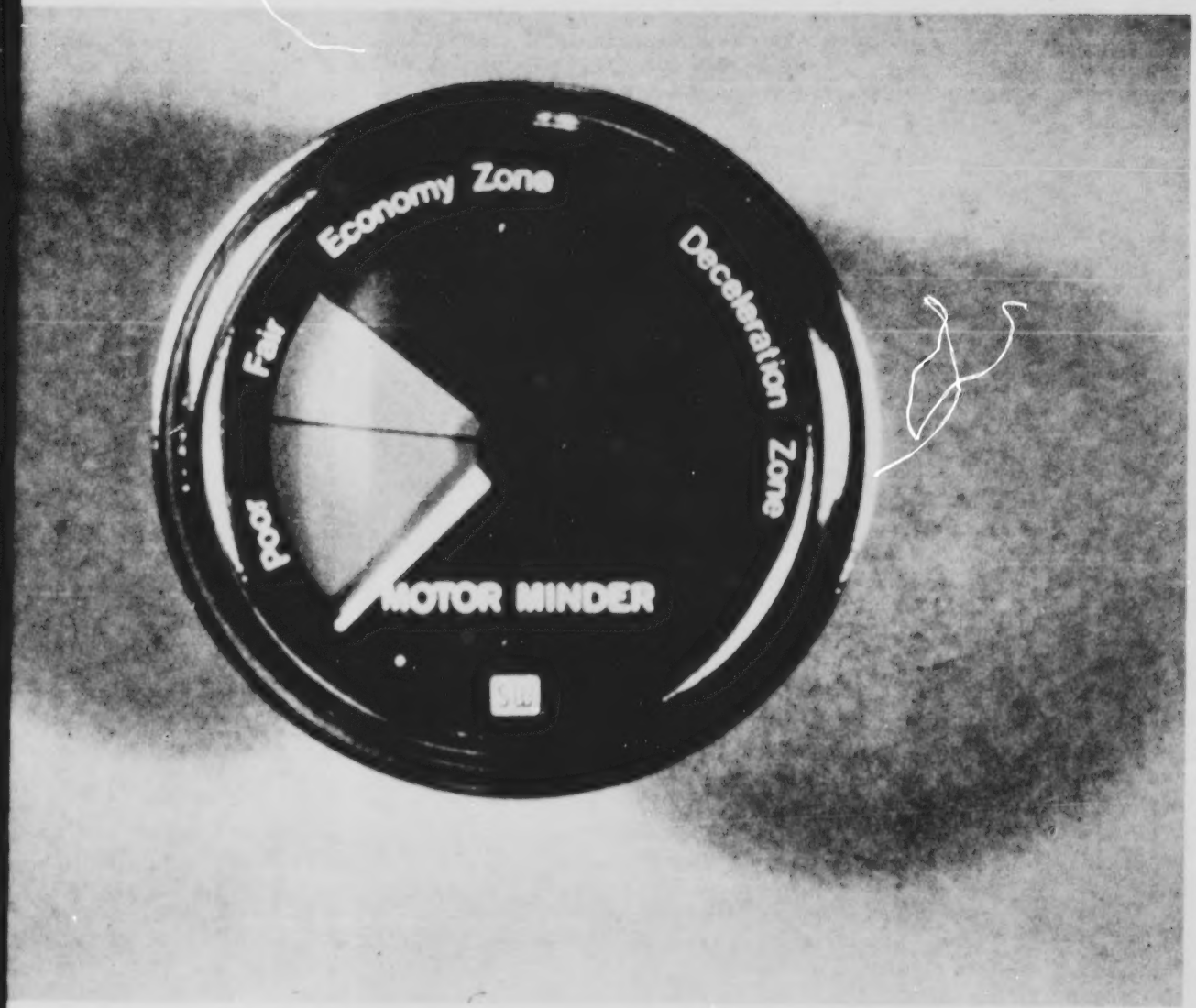


Figure 3-2. "Motor Minder" Dial-Type Manifold Vacuum Gauge (Stewart-Warner)

Figure 3-3. "VacTach" Piston-Type Manifold Vacuum Gauge (C&E Enterprises, Inc.)

The selection of any gauge does not imply that it was judged superior in terms of performance, fuel economy effects, or any other specific characteristics. A true evaluative ranking of all vacuum gauges would require an extensive testing program outside the scope of this project. These gauges were chosen to represent generic types.

3.5. VEHICLE SAMPLE SIZE

Mean and standard deviation data from similar tests were used to determine the approximate number of vehicles needed in each of the five highway segment groups, such that the expected differences had less than a 5 percent chance of being due to random experimental error. This analysis indicated that 60 to 75 vehicles were required in each of the four treatment groups and in the control group. A total of 333 vehicles was selected for inclusion in the highway test.

An analysis of the early highway segment data indicated that a smaller sample size would be adequate for the urban segment. A total of 145 vehicles (5 groups of about 29 vehicles each) was selected for inclusion in the urban test segment. Nine of these vehicles were eventually eliminated from the test. The criteria for removing a vehicle included: severe accident, breakdown of vehicle, and primary driver reassignment. Data collected from these nine vehicles was eliminated from the data base prior to analysis.

The original test plan specified that only vehicles which were assigned to a single driver be used in the test. However, neither NTS nor Clark County possessed enough single-driver vehicles to meet the requirement of a statistically adequate sample size. Approximately 50 percent of the test vehicles had only one driver. The remainder were driven by more than one driver, with the principal driver accumulating about 80 percent of the total test vehicle-miles.

Driver participants were not selected as such; their participation in the test was based upon the fact that they were the drivers normally assigned to the vehicle used in the test. All of these drivers were members of the NTS or Clark County work force. The socio-educational background of the NTS labor pool ranged from relatively little education to post-doctoral education. The participants in the urban segment came from a labor force composed of junior to senior level managerial personnel. Employees who participated in the test received no special treatment. Their participation in the test was presented as a routine task comprising part of their normal workload.

3.6 DRIVER AWARENESS TRAINING COURSE

A review of existing training materials found no existing driver awareness training plan which was both sufficiently comprehensive and applicable to the test objectives. A Driver Awareness Training course was developed for the project with the assistance of several experts in the field of fuel-efficient driving.

The training course was designed to be conducted within a four-hour period: two hours of classroom instruction in fuel-efficient driving techniques followed by a two-hour driving demonstration in an instrumented vehicle. Each student was given an opportunity to drive the vehicle and observe the response of the instruments.

A detailed summary of the training course is presented in Appendix C.

4.0 TEST CONSTRAINTS

Ideally, any experiment should be conducted in an environment which eliminates or at least minimizes extraneous factors that would tend to influence the results. Factors such as weather, driving cycle, legal speed limit, and the like should be held constant if the true relationship between fuel economy and driver awareness education is to be accurately measured. However, a substantial problem arises in such a "laboratory" environment. As the test environment is increasingly displaced from the real (i.e., uncontrolled) environment, the driver's response to the test environment becomes less representative of his response to the real environment. Earlier tests have already shown that fuel economy improvements in the 10 to 20 percent range are common in such controlled environments. Although these earlier tests show what is possible under ideal conditions, their usefulness in describing driver behaviors has been confounded by efforts to eliminate all sources of extraneous variation.

The opposite extreme, no test controls whatsoever, is equally undesirable. Under such conditions, it is virtually impossible to obtain accurate data or to interpret results.

Therefore, this project attempted to identify and minimize major sources of uncontrolled variance, within the additional constraint that such efforts did not require the drivers to alter their normal driving behavior except in response to the training course and/or vacuum gauge. The following test constraints and limitations are noted:

4.1 DRIVER RESPONSE TO THE PROJECT

In any test involving or requiring human response or interaction, it is always possible that the participants, knowing that a test is being conducted,

will respond differently than they would without such knowledge. This phenomenon is known as the Hawthorne effect. For example, it would be expected that some test drivers would interact with one another during the test and that information concerning the test objectives and economy-driving techniques would be exchanged among the various groups. This may be especially true of the control group members, who received no formal information about the project or about driver aid devices. The high level of driver interest evident in responses to the questionnaire reinforces this hypothesis.

In addition, it is probable that at least some drivers, perceiving the overall test objectives, would attempt to perform well in order to demonstrate their accomplishment to their peers and superiors. An attempt was made to reduce this effect by preventing dissemination of test data to the drivers until completion of the project. It is not the presence or absence of motivation or pressure that is at issue here, but rather the source of such influences. A driver who carefully monitors his fuel economy and attempts to improve his driving habits may do so entirely because of his own interests (intrinsic motivation). In fact, this is exactly the response desired in this project. The relative absence of extrinsic motivation in this test was necessary in order that the results would show the effects of intrinsic motivation. Any other influences would be fleet-specific. Therefore, the test managers were directed not to discuss the project or provide performance information or any other type of extrinsic motivation to any of the participating drivers.

4.2 DRIVER/VEHICLE ASSIGNMENTS

The originally specified test condition of single driver/vehicle assignments could not be completely met during the highway test segment. While most vehicles had one principal driver, a number of the test vehicles were driven

by more than one person. However, the vehicle miles driven by these other personnel are estimated to be less than 20 percent of the total test vehicle miles. The result of this mixing would be to confound the effects of the various treatments to some extent, and to decrease the relative differences between the treatments. Driver/vehicle assignments during the urban segment were better controlled, and thus little diffusion was anticipated.

4.3 SPEED LIMIT ENFORCEMENT

The highway test segment was conducted at the Nevada Test Site, where a maximum 55 mph speed limit is strictly enforced. It is thus expected that fuel economy improvements observed at this site will be somewhat less that would be expected in a normal enforcement environment. The average incremental gain in fuel economy normally realized with a speed reduction from 55 to 50 mph is in the three to five percent range. The effect of driver education and/or the use of driver aids would normally be expected to result in some decrease in highway speed. This incremental effect may be small or nonexistent in the highway segment of the test project, since the strict enforcement procedures of the Federal Government make it likely that these drivers "normally" adhere to a speed limit of 55 mph.

4.4 WEATHER EFFECTS

The climate within which both the urban and the highway segments of the test were conducted is typical of the arid Southwest region. Annual temperatures range from 0°F to 115°F. Rainfall level is low overall (four inches at an elevation of 3,000 feet to about 12 inches at an elevation of 7,000 feet), but tends to occur with great intensity over short periods of time. Severe dust storms are frequent. Low temperatures, wet roads, and the presence of dust, individually or in combination, all act to reduce fuel economy.

In terms of weather effects, the substantive difference which should be noted between test phases of the highway segment is that Phase I was conducted in an environment of decreasing temperatures (July through January), while Phase II was conducted while temperatures were increasing (February through July).

The urban segment did not require Phase I testing, as the baseline data had already been collected. Thus, the urban testing took place solely in an environment of falling temperatures (July through December).

5.0 RESULTS

5.1 TEST RESULTS

The test results are presented using two different methods of data aggregation. Table 5-1 presents the aggregated fuel economy results assuming that each vehicle's monthly fuel economy reading is of equal importance, regardless of miles traveled or fuel consumed. The average fuel economy of each vehicle was computed for each month (monthly miles divided by monthly gallons). These values were then summed within each test group, and divided by the number of vehicle-months, resulting in what is termed the Average Group Fuel Economy for each of the test groups.

Another equally-acceptable form of data aggregation is presented in Table 5-2. In this case, the assumption is that each gallon of fuel consumed is equally important. Therefore, the fuel economy change of a vehicle which consumed a disproportionately large amount of fuel is given more relative importance. This approach produces what is termed Fuel-Weighted Average Group Fuel Economy.

Statistical analysis was performed only on the Average Group Fuel Economy values. The Fuel-Weighted data were not analyzed statistically since there appears to be some controversy in the statistical community as to the validity and the meaning of the results of such an analysis.

The question arises as to which fuel economy value is the best estimate of untreated fuel economy. If it can be established that all of the groups were essentially the same in terms of fuel economy during Phase I, then the best estimate of Phase II untreated fuel economy is the Phase II control group results. Comparisons of the treated groups with the Phase II control group are then the best estimates of the net effects of the various treatments.

TABLE 5.1

TEST RESULTS BASED UPON AVERAGE GROUP FUEL ECONOMY

	HIGHWAY SEGMENT				URBAN SEGMENT*			
GROUP	Phase I MPG	Phase II MPG	Change: Phase II-Phase I Δ MPG (%)	Difference: Phase II-Phase II Control Δ MPG (%)	Background (Phase I) MPG	Test (Phase II) MPG	Change: Background-Test Δ MPG (%)	Difference: Test-Control Δ MPG (%)
1. (Piston-Type Vacuum Gauge)	12.81	13.34	0.53 (4.1)	0.48 (3.7)	11.10	10.7	−0.40 (−3.6)	−0.14 (−1.3)
2. (Control)	12.53	12.86	0.33 (2.6)	——	10.4	10.84	0.44 (4.2)	——
3. (Training)	12.95	13.35	0.40 (3.1)	0.49 (3.8)	10.18	10.95	0.77 (7.6)	0.11 (1.5)
4. (Training plus Dial--Type Vacuum Gauge)	13.06	13.65	0.59 (4.5)	0.79 (6.1)	10.14	10.68	0.54 (5.3)	−0.16 (−1.5)
5. (Dial-Type Vacuum Gauge)	12.72	13.24	0.52 (4.0)	0.38 (3.0)	10.96	11.50	0.54 (4.9)	0.66 (6.1)
All	12.81	13.29	0.48 (3.7)	0.43 (3.3)	10.56	10.93	0.37 (3.5)	0.09 (0.8)

*The statistical significance of the urban results is qualified.
See Section 5.1.1.

Comparisons within each group of the Phase II and Phase I results would include these treatment effects, but the effects of such extraneous variables as weather, driving patterns, use of air-conditioning, and the like would also be reflected in these values. Thus, such comparisons would be confounded to a degree which is not estimable.

If it cannot be established that the Phase I group fuel consumption is essentially the same, the Phase II control group fuel economy cannot be considered as the best estimate of untreated fuel economy. In this case, the only reasonable comparison is between Phase I and Phase II for each group. As stated above, such comparisons will include the effects of extraneous variables and thus may not accurately reflect the net effects of the treatments. Therefore, the most meaningful results are inter-group comparisons of Phase II fuel economy data, if analysis of Phase I (untreated) results establishes that the groups are essentially similar.

5.1.1 Average Group Fuel Economy Results

An analysis of variance performed on the Phase I highway segment data determined that no statistically significant fuel economy differences were found at a five percent significance level. Therefore, we cannot reject the hypothesis that all five highway test groups are essentially the same.

An analysis of variance was then conducted on the Phase II highway segment data to determine whether any group differed significantly from any of the others. The results of this analysis indicate that at least one group showed a significant difference from the others. A subsequent Newman-Kuels statistical test revealed that all four of the treated test groups now differed significantly from the control group. In other words, in Phase II each of the four highway segment test groups experienced significantly improved fuel

economy when compared to the control group. Similar statistical comparisons between Phase I and Phase II data verify significant fuel economy increases for all four treatment groups, but no significant increase for the control group.

The greatest difference in Phase II was achieved by Group 4 (training plus dial-type vacuum gauge), which obtained an average group fuel economy 6.1 percent greater than that of the control group. The other three treatment groups were from 3 to 3.8 percent greater than the control group. The observed effect of the driver energy conservation training used in combination with a dial-type vacuum gauge was approximately twice as great as the effect achieved by using either treatment alone. In addition, the statistical analysis does not establish any significant difference in effect between the two types of vacuum gauges tested.

While the analysis of variance performed on the Phase I highway segment data does not reject the hypothesis that the untreated groups are essentially the same, it does not prove that they are the same. Therefore, inter-phase comparisons of these data are also presented. In this case, Group 4 continues to show the greatest improvement (Phase II is 4.5 percent greater than Phase I), while the other three treatment groups show improvements in the 3.1 percent to 4.1 percent range. Again, there appears to be no difference between the two types of vacuuum gauges tested.

It is also possible to compare test results by assuming that inter-phase changes which occurred in the control groups accurately reflect extraneous environmental and motivational factors which should be equally discounted from the treatment groups. For example, the highway segment control group inter-phase improvement was 2.6 percent. If it were assumed that the four treatment

groups would have changed by this amount if they had not been treated, then the "actual" improvements of Groups 1, 2, 3, and 5 would be 1.5, 0.5, 1.9, and 1.5 percent, respectively. However, this approach suffers from several problems. First, its use implies that the Phase I groups are inherently different from each other in terms of fuel economy results. This implication is not supported by the Phase I analysis of variance. Second, it assumes that the interphase improvement of the control group is significant. Again, the statistical analysis does not support this assumption. Finally, it assumes that the interphase improvement of the control group is due to non-treatment (i.e., environmental) factors which would equally affect all other groups as well. A review of the questionnaire results (Appendix D, Question 2) shows that 21 percent of the control group participants felt that they had changed their driving habits in response to the project (versus 60 percent of the treatment group participants). This could be due in part to knowledge that a fuel economy test was in progress and/or to the acquisition of specific information concerning fuel-efficient driving techniques. Therefore, the interphase improvement of the control groups can at best be ascribed to a combination of the following factors: random variation, weather effects, driving cycle effects, the Hawthorne effect, and the informal exchange of information about driving techniques. The relative degree to which each of these factors affects the interphase comparisons is not known. Therefore, the use of interphase comparisons discounted by the control group requires several assumptions which are not supported by the analysis. This does not prove that such a comparison is wrong, only that it cannot be supported by the data.

The urban test segment data were analyzed in similar fashion. The background data analysis established that no significant differences had

existed among the five untreated groups prior to the test phase, at a five percent significance level. However, if a ten percent significance level had been specified, some significant differences would have been found, and the hypothesis of equivalent untreated groups would have been rejected. The statistical test only states that we cannot be certain (with a five percent or less chance of being wrong) that the treatment groups are different from the control group.

Since the results of the statistical analysis approach rejection of the hypothesis, it must be understood that the urban results are of lesser significance and therefore of less value than the highway results. This caveat is reinforced by the discovery that approximately ten percent of the urban fleet vehicles lacked sufficient background data and thus were not included in the analysis of variance performed on the background data. Since the problems encountered do not prove that these results are invalid, but show only that it cannot be established that they are valid, a decision was made to include the urban results in this report.

On the presumption that the analysis of variance of the (untreated) urban segment background data support the hypothesis of essentially equivalent groups, a similar analysis of the urban test (treated) phase was used to establish that at least one group differed substantially from the others at this point. Further comparisons revealed that the dial-type vacuum gauge group (Group 5) differed significantly from the other four groups (including the control group). No statistical comparisons of the urban segment background and test data were conducted, because the background data for a substantial proportion of the vehicles were not available.

However, the results of the urban segment are somewhat questionable, due to the problems stated above. Further analysis of the data is planned in order to determine whether these qualifications affect the statistical significance of the results.

5.1.2 Fuel-Weighted Average Group Fuel Economy Results

As discussed in Section 5.1, it is also possible to compare the test results on the basis that each gallon of fuel consumed has equal importance. This has been termed Fuel-Weighted Average Group Fuel Economy and highway segment results are presented in Table 5.2. Urban segment data were not available in this form. Since there exists some controversy with respect to the proper statistical methods to be used with such weighted data, no statistical analysis of these results had been conducted at the time this report as issued. Statistical research into this and related areas is presently being conducted for the DOE by H. T. McAdams of Falcon Research and Development, Buffalo, New York. If this is successful, statistical analysis of these weighted data may be conducted at a later date and may form the basis of a supplementary report.

The Fuel-Weighted Group Fuel Economy results differ in several respects from the Average Group Fuel Economy results presented in Section 5.1.1. The means are different and the relative differences between the means are different, within both phases and between each phase.

TABLE 5.2

TEST RESULTS BASED UPON FUEL-WEIGHTED AVERAGE GROUP FUEL ECONOMY

	HIGHWAY SEGMENT				URBAN SEGMENT			
GROUP	Phase I MPG	Phase II MPG	Change: Phase II-Phase I Δ MPG (%)	Difference: Phase II-Phase II Control Δ MPG (%)	Background (Phase I) MPG	Test (Phase II) MPG	Change: Background-Test Δ MPG (%)	Difference: Test-Control Δ MPG (%)
1. (Piston-Type Vacuum Gauge)	12.73	12.71	−0.02 (−0.2)	0 (0)	N/A*	10.49	N/A	−0.72 (−6.4)
2. (Control)	12.51	12.71	0.20 (1.6)	——	N/A	11.21	N/A	——
3. (Training)	12.84	12.98	0.14 (1.1)	0.27 (2.1)	N/A	10.97	N/A	−0.24 (−2.1)
4. (Training plus Dial-Type Vacuum Gauge)	12.67	13.37	0.70 (5.5)	0.66 (5.2)	N/A	10.82	N/A	−0.39 (−3.5)
5. (Dial-Type Vacuum Gauge)	12.89	13.28	0.39 (3.0)	0.57 (4.5)	N/A	11.94	N/A	0.73 (6.5)
All	12.72	13.00	0.28 (2.2)	0.23 (2.3)	N/A	11.09	N/A	−0.12 (−1.1)

*Not available.

If it is assumed that the best estimate of untreated fuel economy is the Phase II control group, then the highway segment treatment group which achieved the greatest fuel economy improvement is again Group 4 (training plus dial-type vacuum gauge), with 5.1 percent greater fuel economy than the Phase II control group. The remaining treatment groups experienced improvements from zero to 4.4 percent. While Group 1 (piston-type vacuum gauge) did not improve, this cannot be considered significant, since these data were not statistically analyzed. Inter-phase comparisons again indicate that Group 4 experienced the greatest relative improvement.

5.1.3 Trend Analyses

The monthly fuel economies of each of the test groups for both test phases and for each of the data aggregation methods used are presented in figures 5.1 through 5.18. A regression analysis of the Phase I highway segment average group fuel economy on ambient temperature indicated that ambient temperature alone could not account for the observed effects. It can also be seen that while a consistant fuel economy degradation is present in the average group monthly data, this effect is not as evident (with the exception of Group 4) in the fuel-weighted data. This appears to indicate that such degradation (probably primarily due to a combination of decreasing ambient temperature and tune-up degradation) is more prevalent in those vehicles which consumed less than their numerical proportion of fuel and hence, had less effect on the fuel-weighted data.

It is also observed that many of the figures indicate a linear or exponential decrease in Phase II fuel economy. This may be indicative of a gradual loss of learned skills, loss of interest, or a diminution of the Hawthorne Effect over time. It could also reflect the effect of tune-up degradation, although

this by itself is not considered a very important factor during the time period in which the test was conducted.

In summary, the trend data indicate some interesting although somewhat conflicting time effects. Other than attempting to correlate fuel economy with ambient temperature, no further statistical analyses of the trend data had been undertaken at the time this report was issued.

5.1.4 Other Test Data

As a result of the data collection required for the analyses discussed in Section 5.1.1, it was possible to aggregate the data in several different forms and to provide additional test data which were not directly related to the primary test objectives. These data are presented in Appendix E.

5.1.5 Summary of Statistical Findings

The results obtained in the Driver Aid and Education test project generally establish that a program of driver energy conservation awareness training combined with educated use of a dial-type vacuum gauge can result in measurable and statistically significant fuel economy improvement in the area of five percent. Additionally, the test results indicate that driver awareness training alone or the use of a vacuum gauge alone can improve fuel economy, although the magnitude and statistical validity of these improvements are less substantial than the improvements obtained through the use of training in conjunction with the dial-type vacuum gauge.

It must be noted that while the test results support the hypothesis that use of driver energy conservation training and/or use of a vacuum gauge can result in meaningful improvements in fuel economy, these findings do not conclusively prove that such a relationship exists. While such a relationship appears to have existed in the test under discussion, the results obtained do not warrant generalization to all fleets and driving conditions.

Only a portion of the large body of data collected during the test project has been subjected to rigorous review and statistical analysis. Further examination of these data may establish relationships which had not been verified at the time this report was issued.

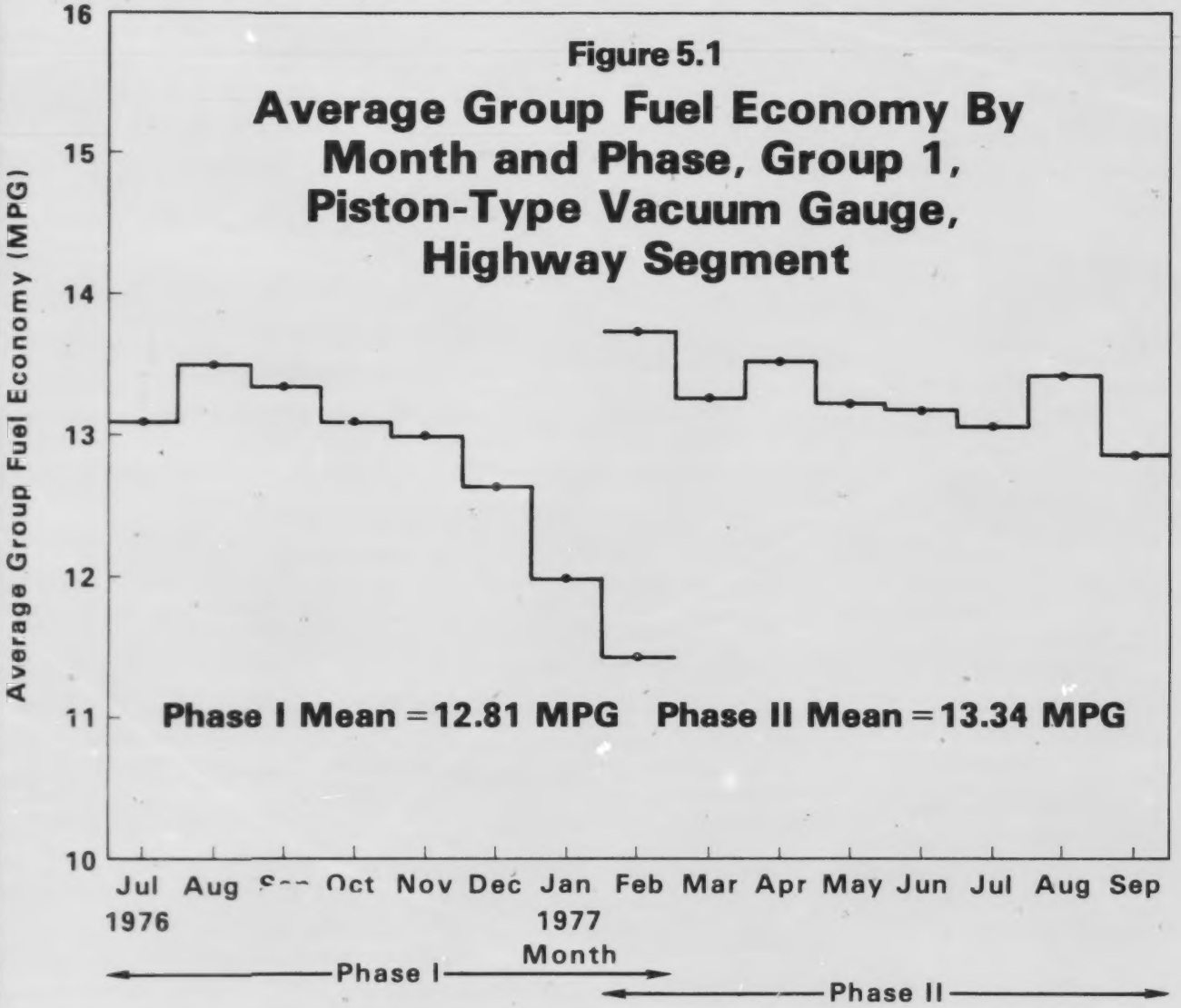
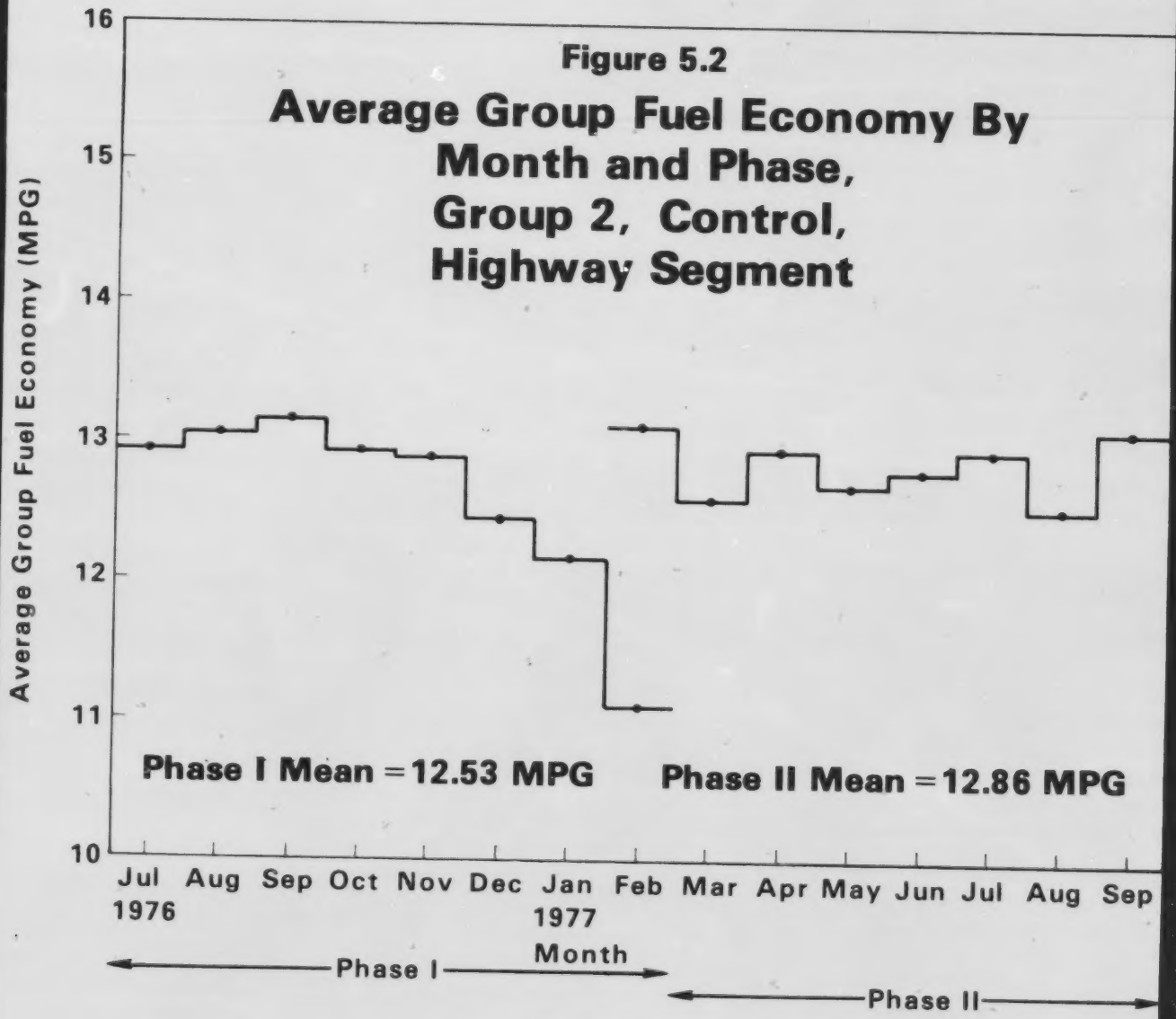


Figure 5.1
Average Group Fuel Economy By Month and Phase, Group 1, Piston-Type Vacuum Gauge, Highway Segment
Average Group Fuel Economy (MPG)
16
15
14
13
12
11
10
Phase I Mean = 12.81 MPG
Phase II Mean = 13.34 MPG
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
1976
1977
Month
Phase I
Phase II

Figure 5.2

Average Group Fuel Economy By Month and Phase, Group 2, Control, Highway Segment



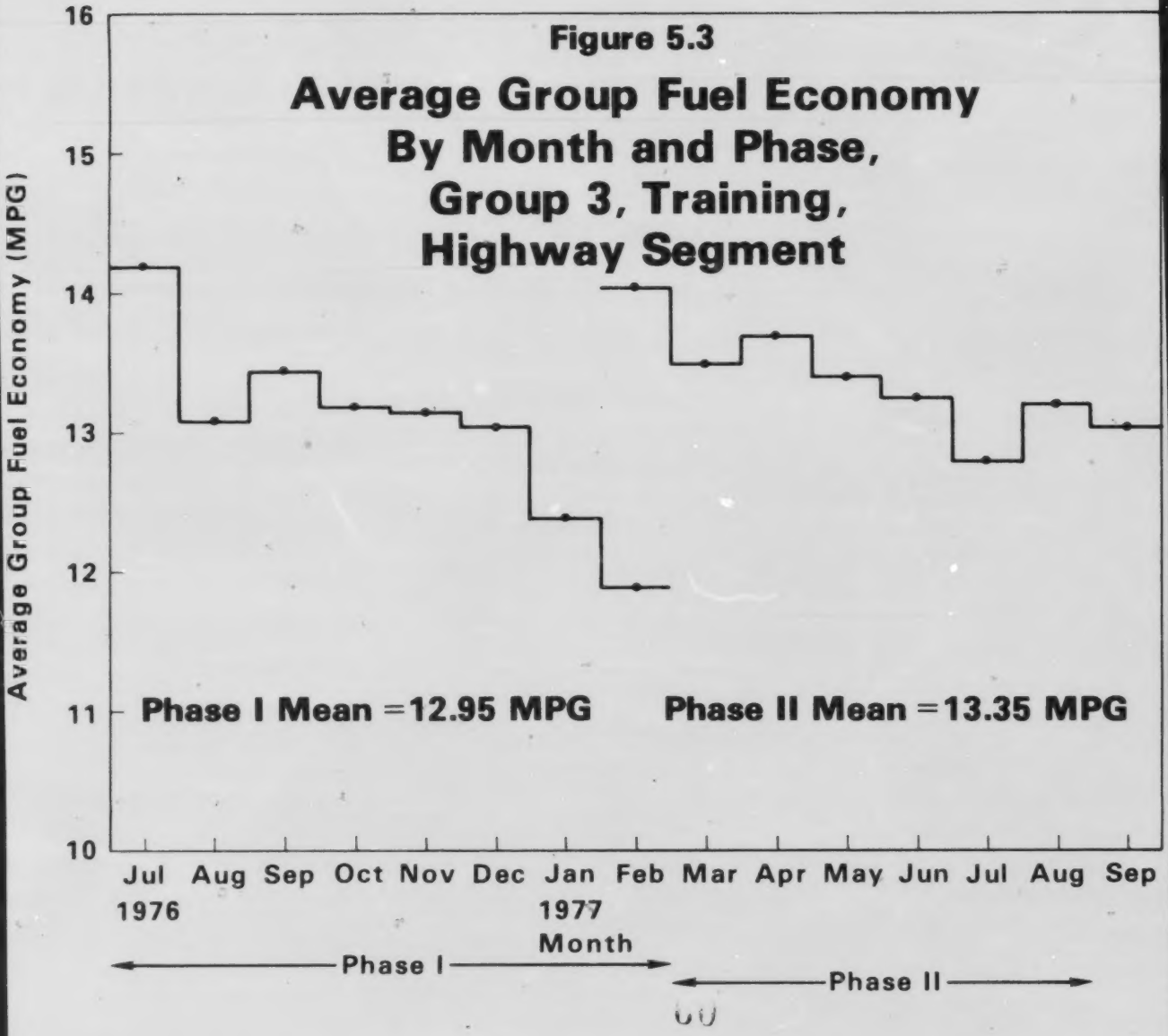


Figure 5.3
Average Group Fuel Economy By Month and Phase, Group 3, Training, Highway Segment
Average Group Fuel Economy (MPG)
16
15
14
13
12
11
10
Phase I Mean =12.95 MPG
Phase II Mean =13.35 MPG
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
1976
1977
Month
Phase I
Phase II

Figure 5.4

Average Group Fuel Economy By Month and Phase, Group 4, Training Plus Dial-Type Vacuum Gauge, Highway Segment

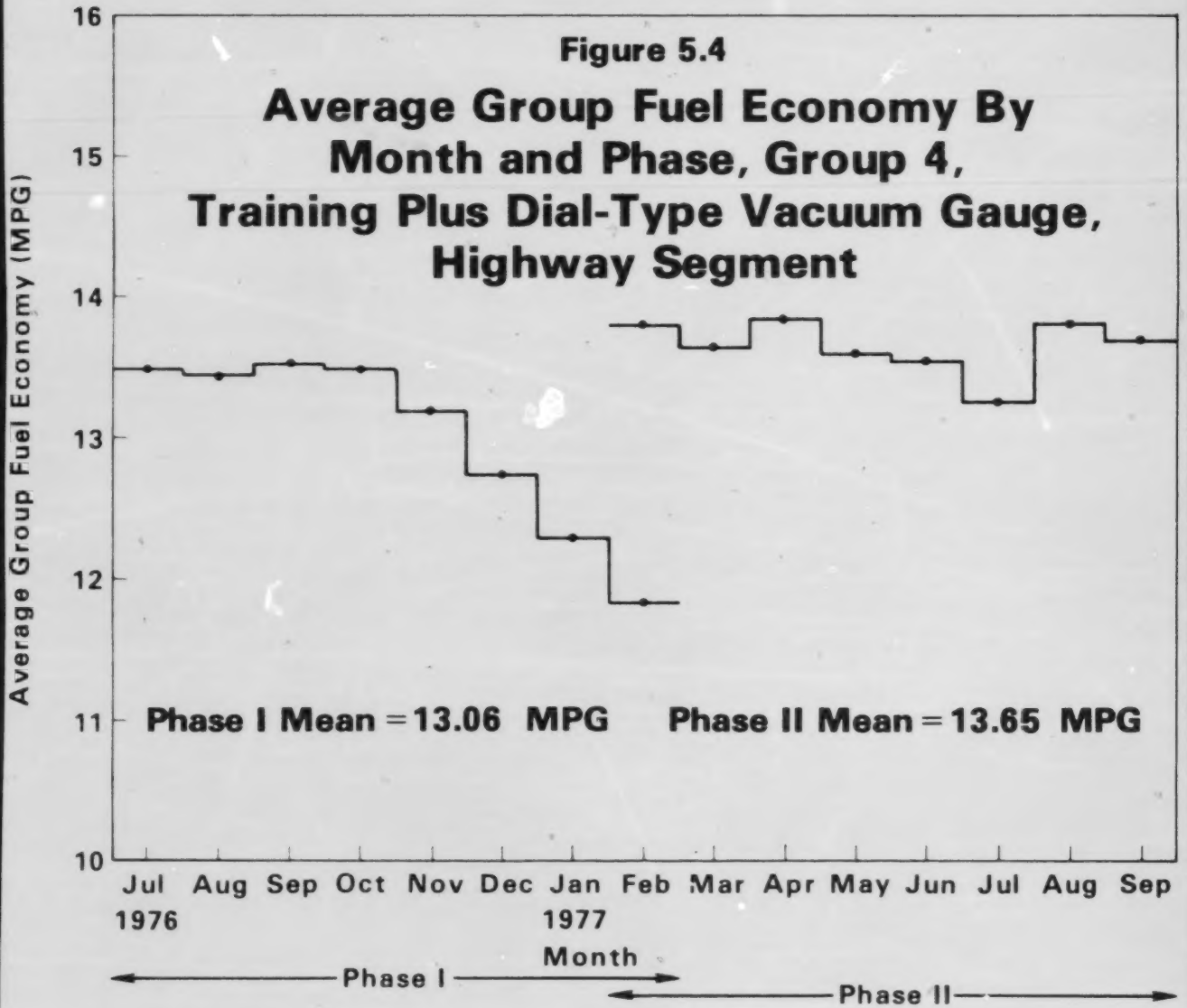


Figure 5.5

Average Group Fuel Economy By Month and Phase, Group 5, Dial-Type Vacuum Gauge, Highway Segment

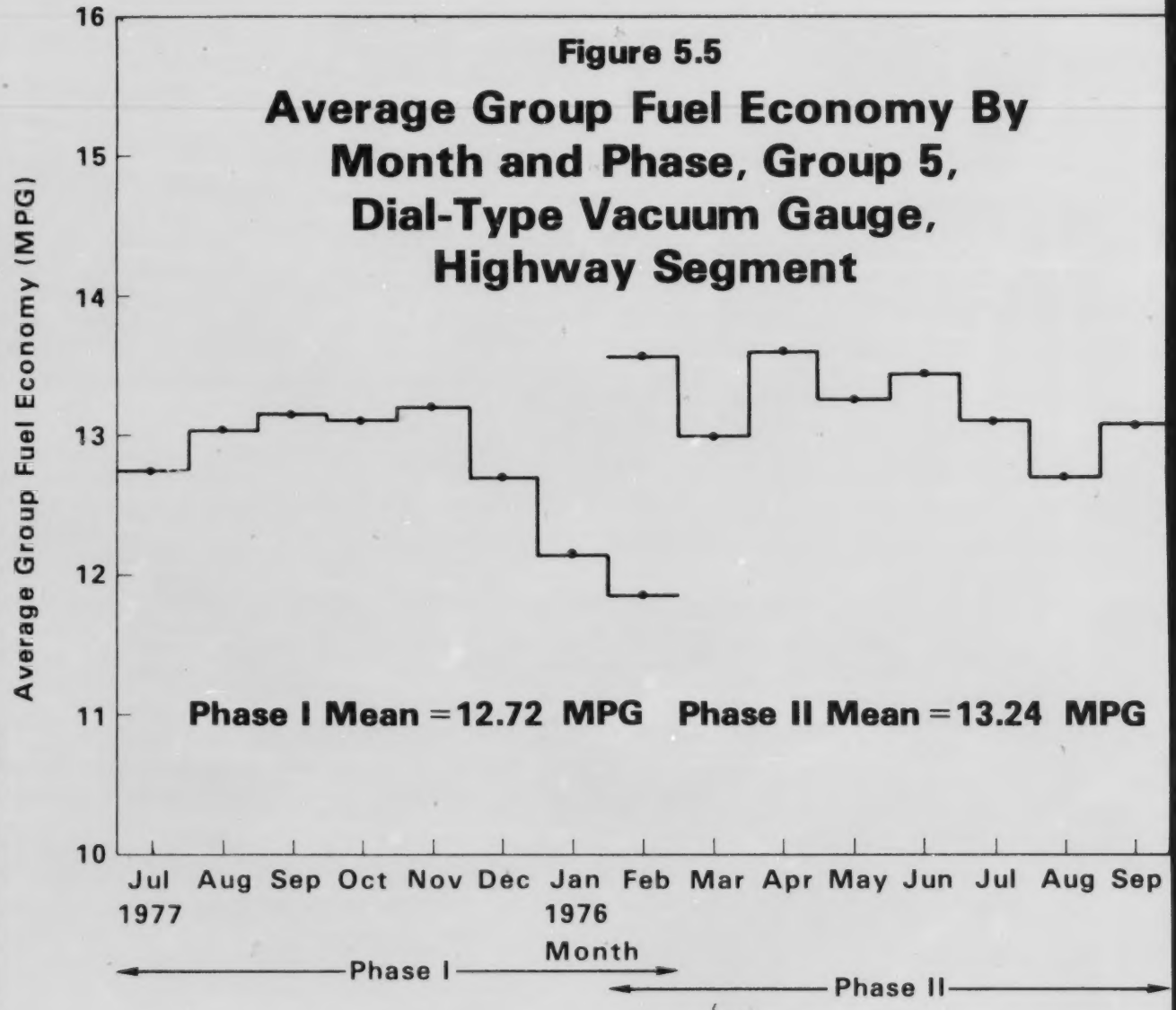


Figure 5.6

Average Fleet Fuel Economy By Month and Phase, All Groups, Highway Segment

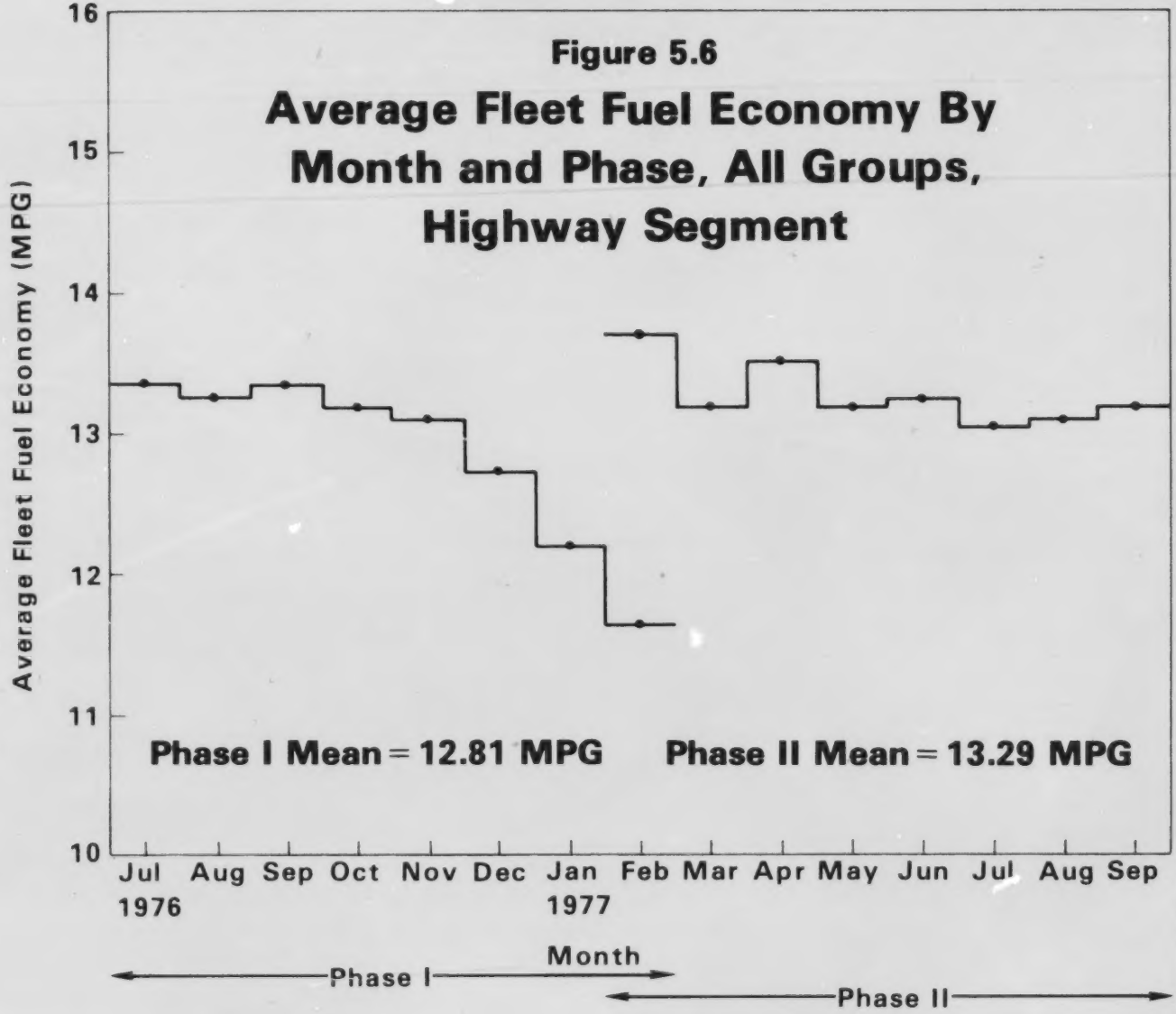


Figure 5.7

Average Group Fuel Economy By Month and Phase, Group 1, Piston-Type Vacuum Gauge, Urban Segment

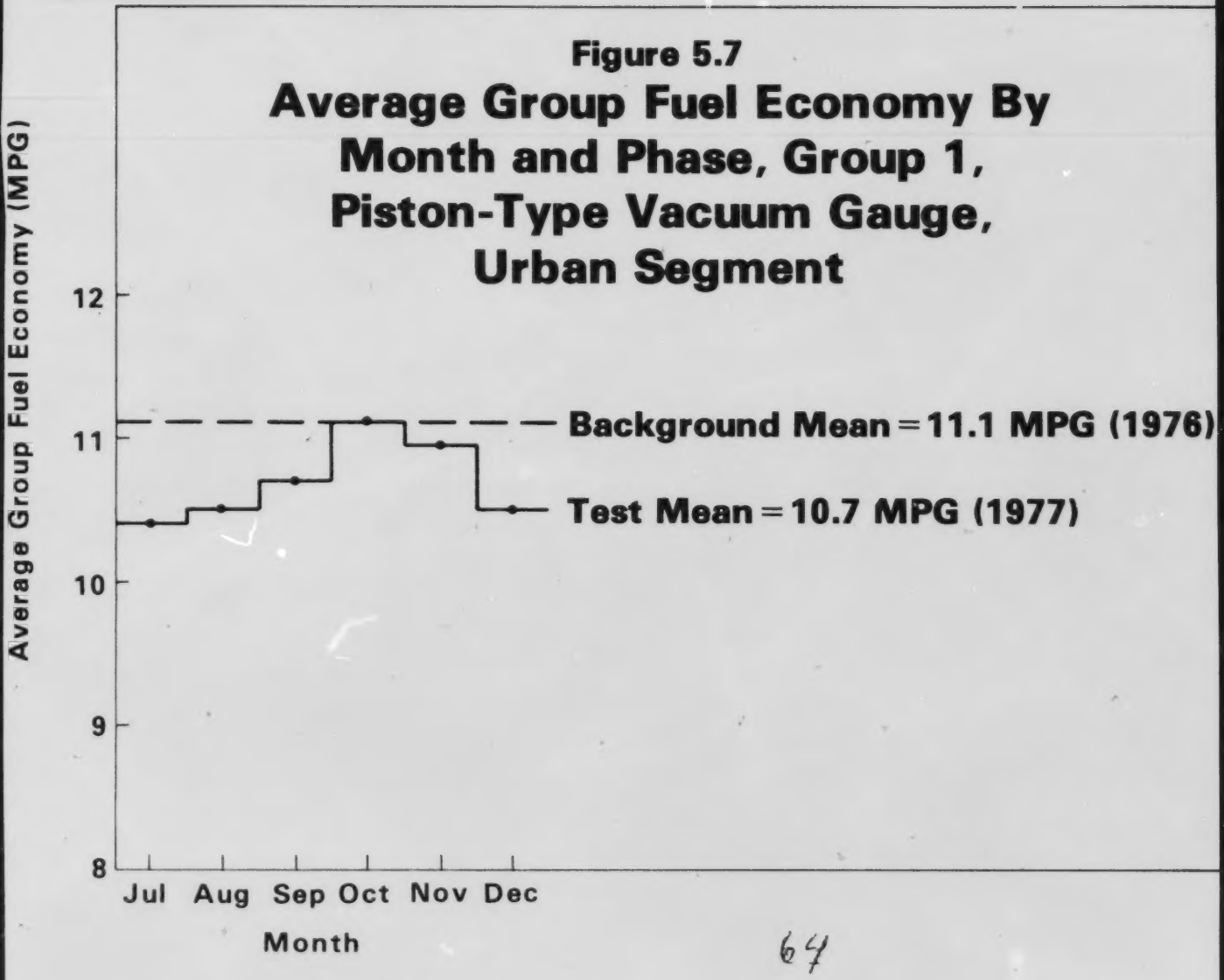


Figure 5.8

Average Group Fuel Economy By Month and Phase, Group 2, Control, Urban Segment

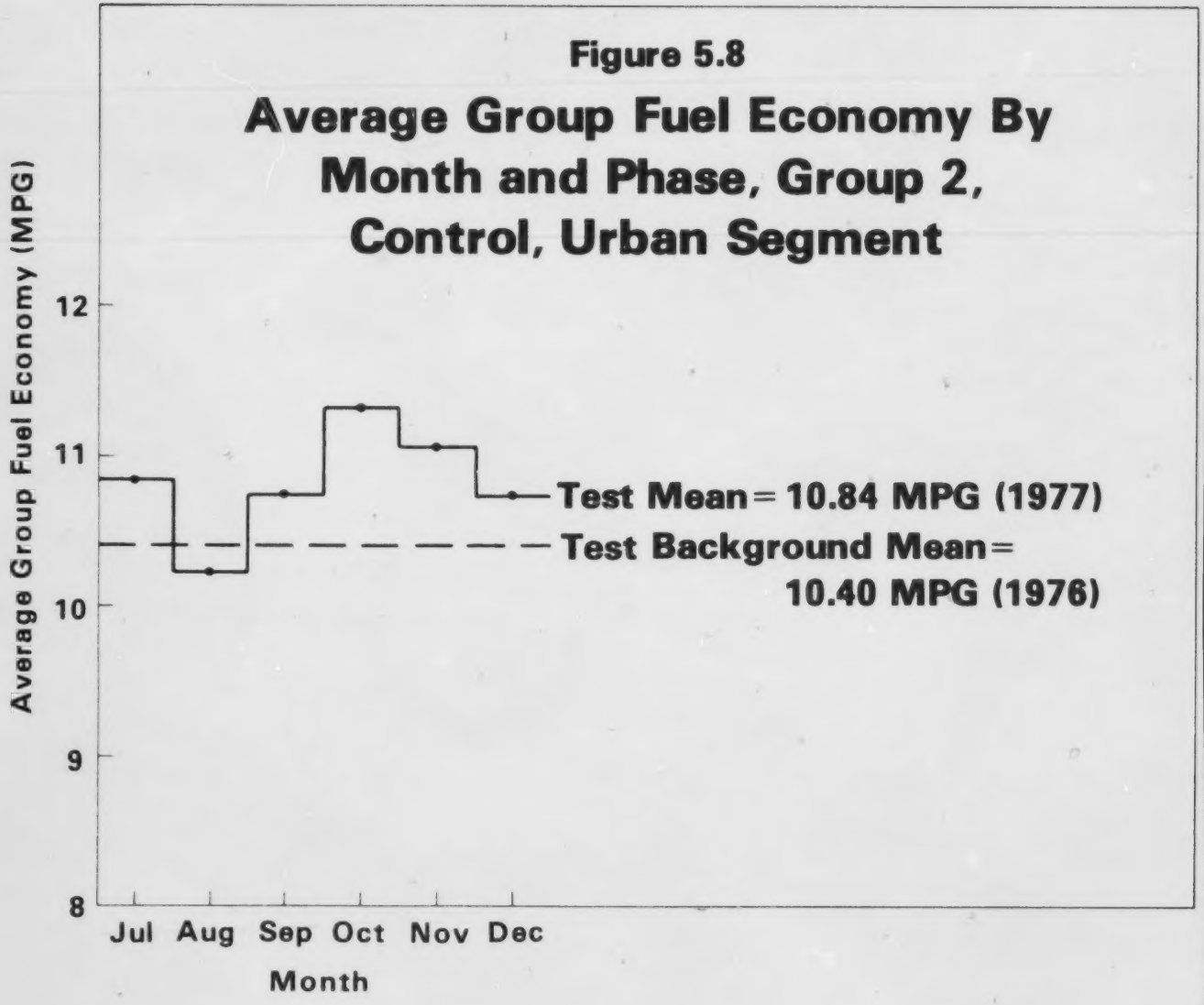


Figure 5.9

Average Group Fuel Economy By Month and Phase, Group 3, Training, Urban Segment

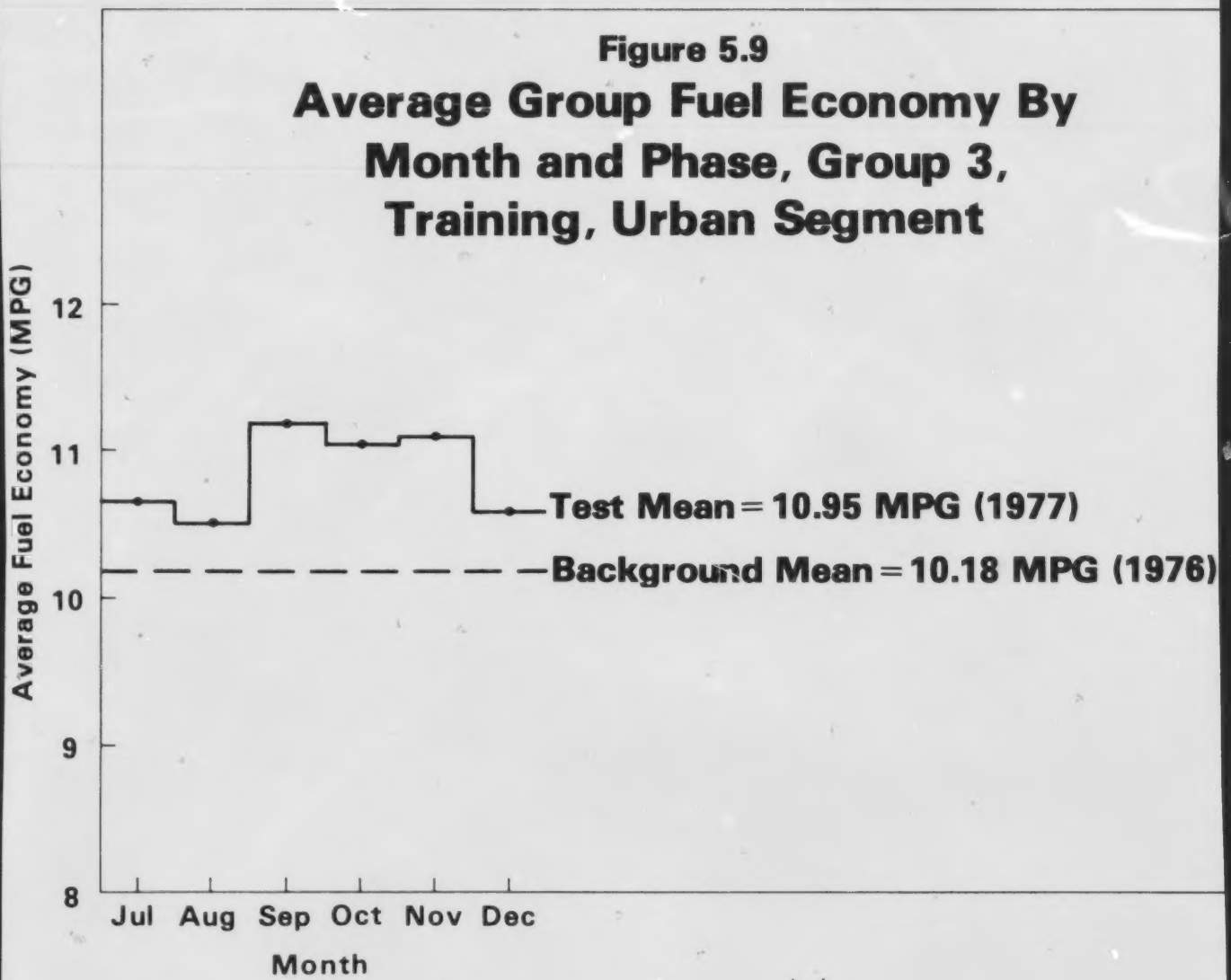


Figure 5.10

Average Group Fuel Economy By Month and Phase, Group 4, Training Plus Dial-Type Vacuum Gauge, Urban Segment

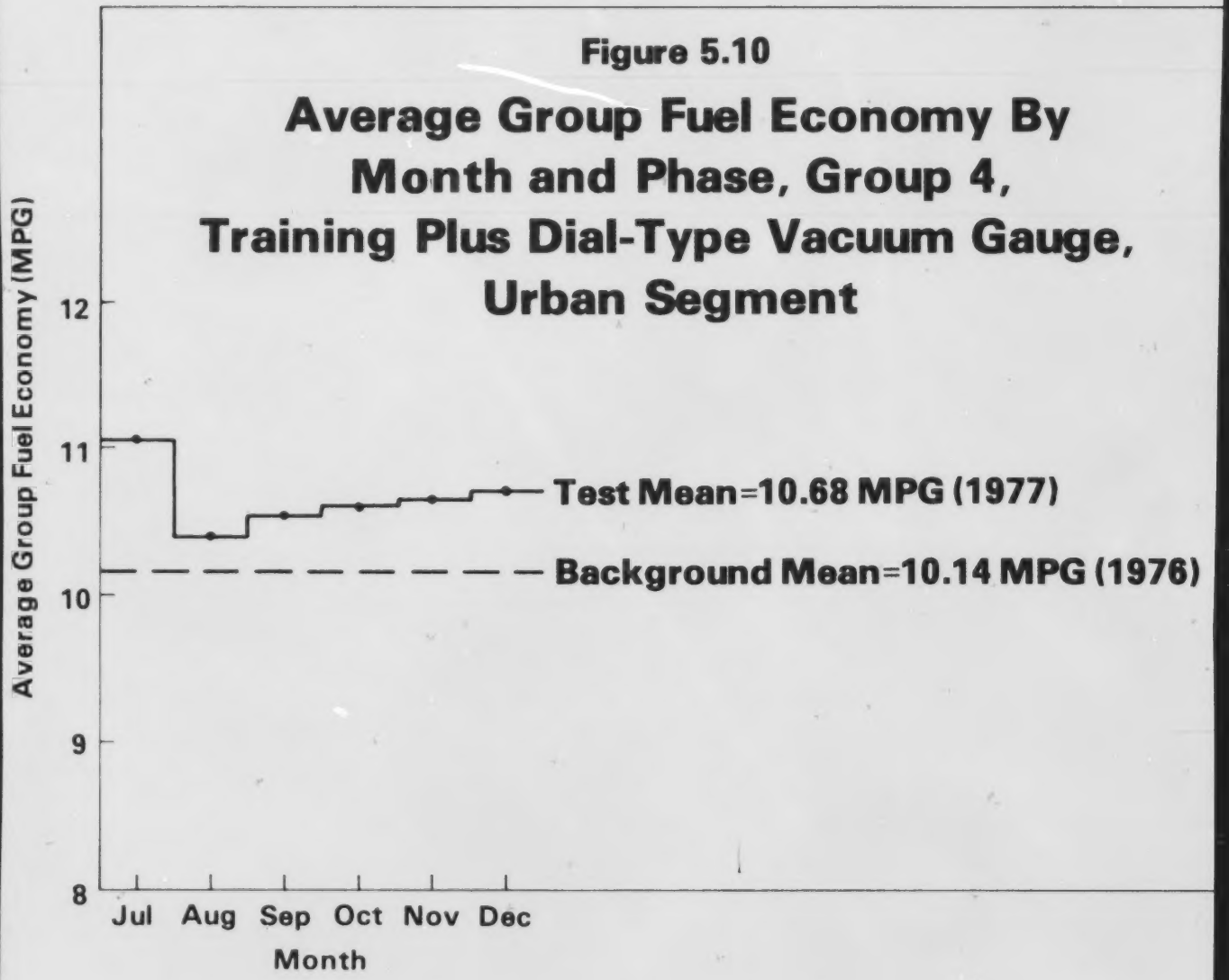


Figure 5.11

Average Group Fuel Economy By Month and Phase, Group 5, Dial-Type Vacuum Gauge, Urban Segment

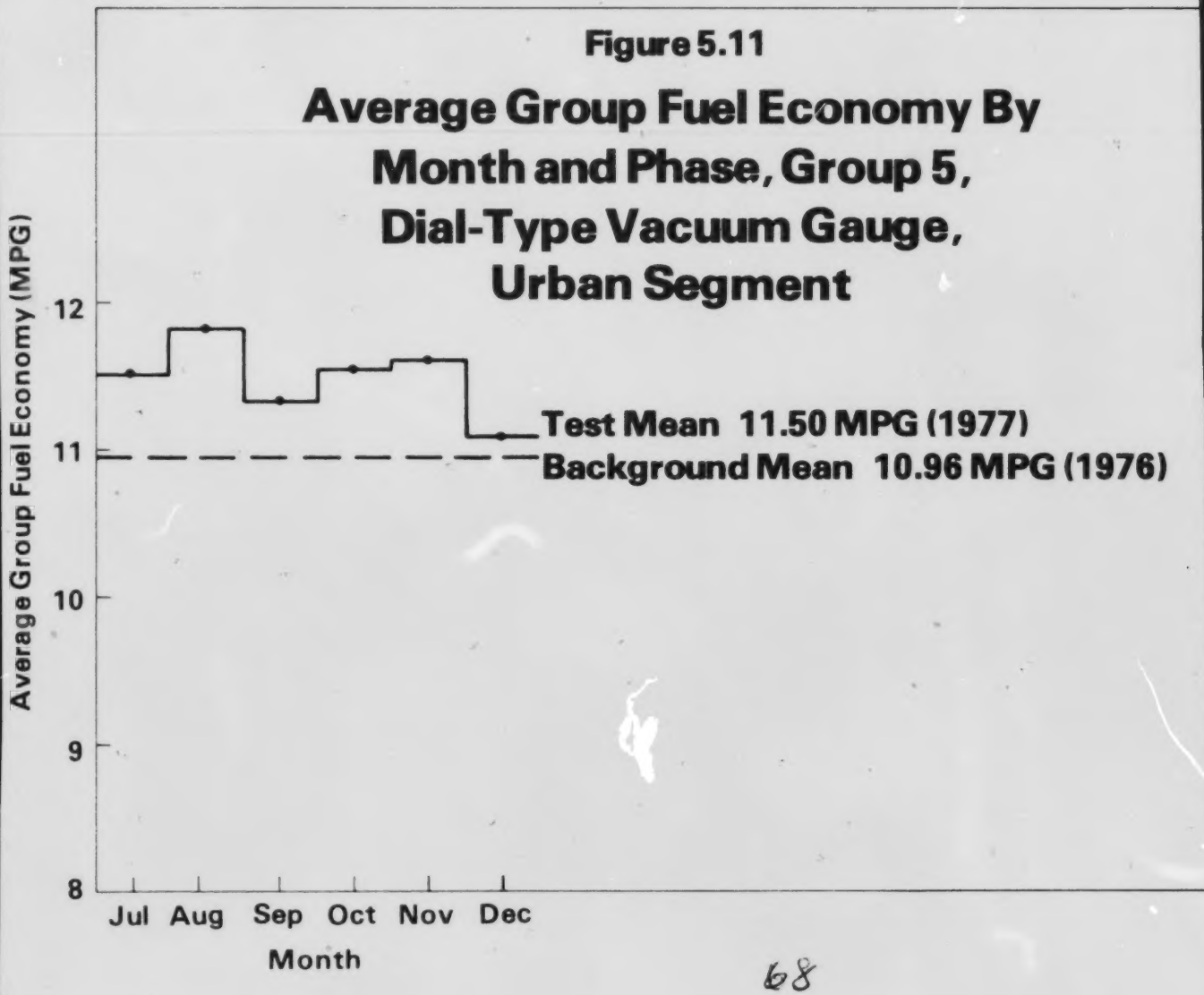
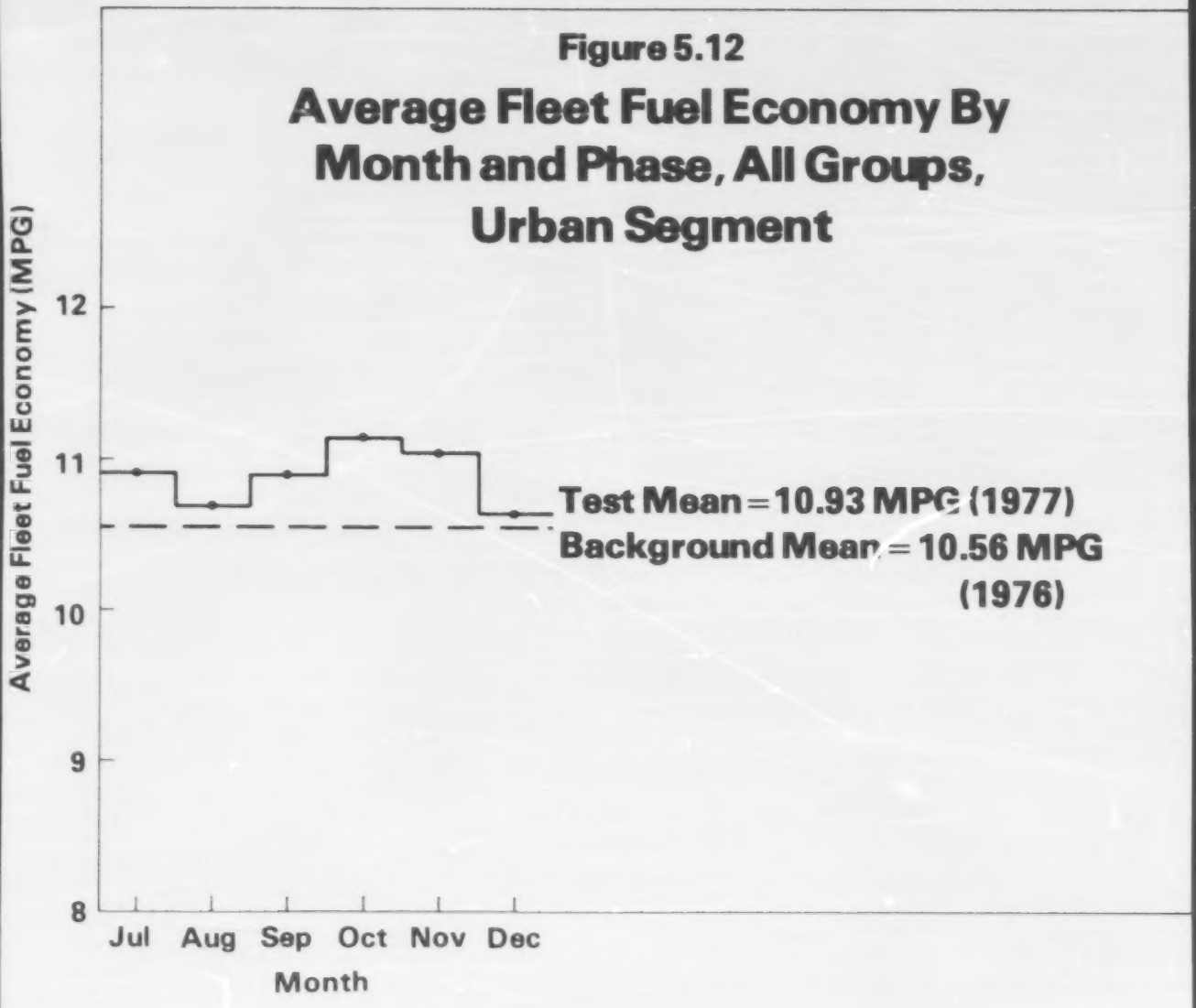


Figure 5.12

Average Fleet Fuel Economy By Month and Phase, All Groups, Urban Segment



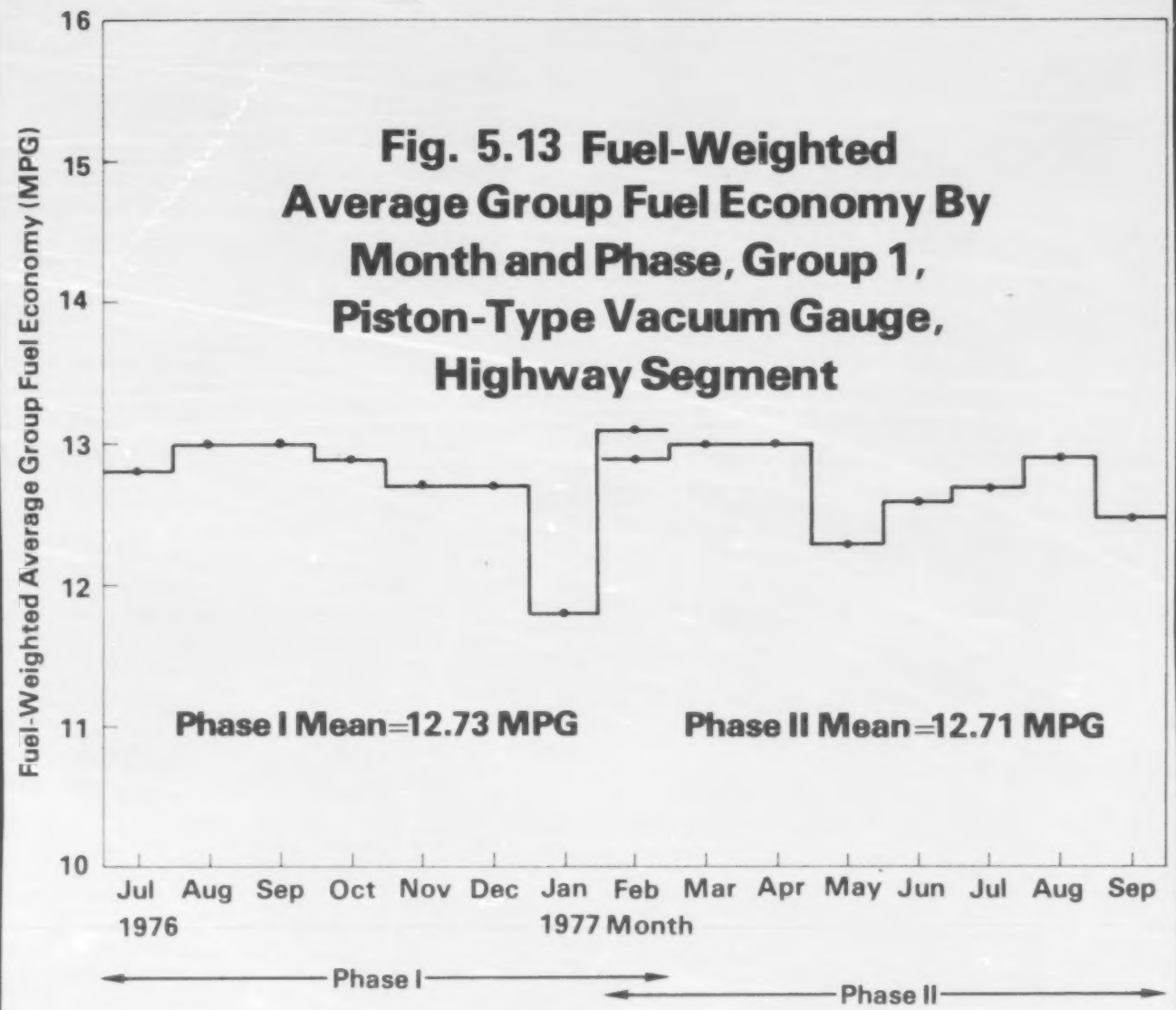


Fig. 5.13 Fuel-Weighted Average Group Fuel Economy By Month and Phase, Group 1, Piston-Type Vacuum Gauge, Highway Segment
Fuel-Weighted Average Group Fuel Economy (MPG)
16
15
14
13
12
11
10
Phase I Mean=12.73 MPG
Phase II Mean=12.71 MPG
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
1976
1977 Month
Phase I
Phase II

Figure 5.14

Fuel-Weighted Average Group Fuel Economy By Month and Phase, Group 2, Control, Highway Segment

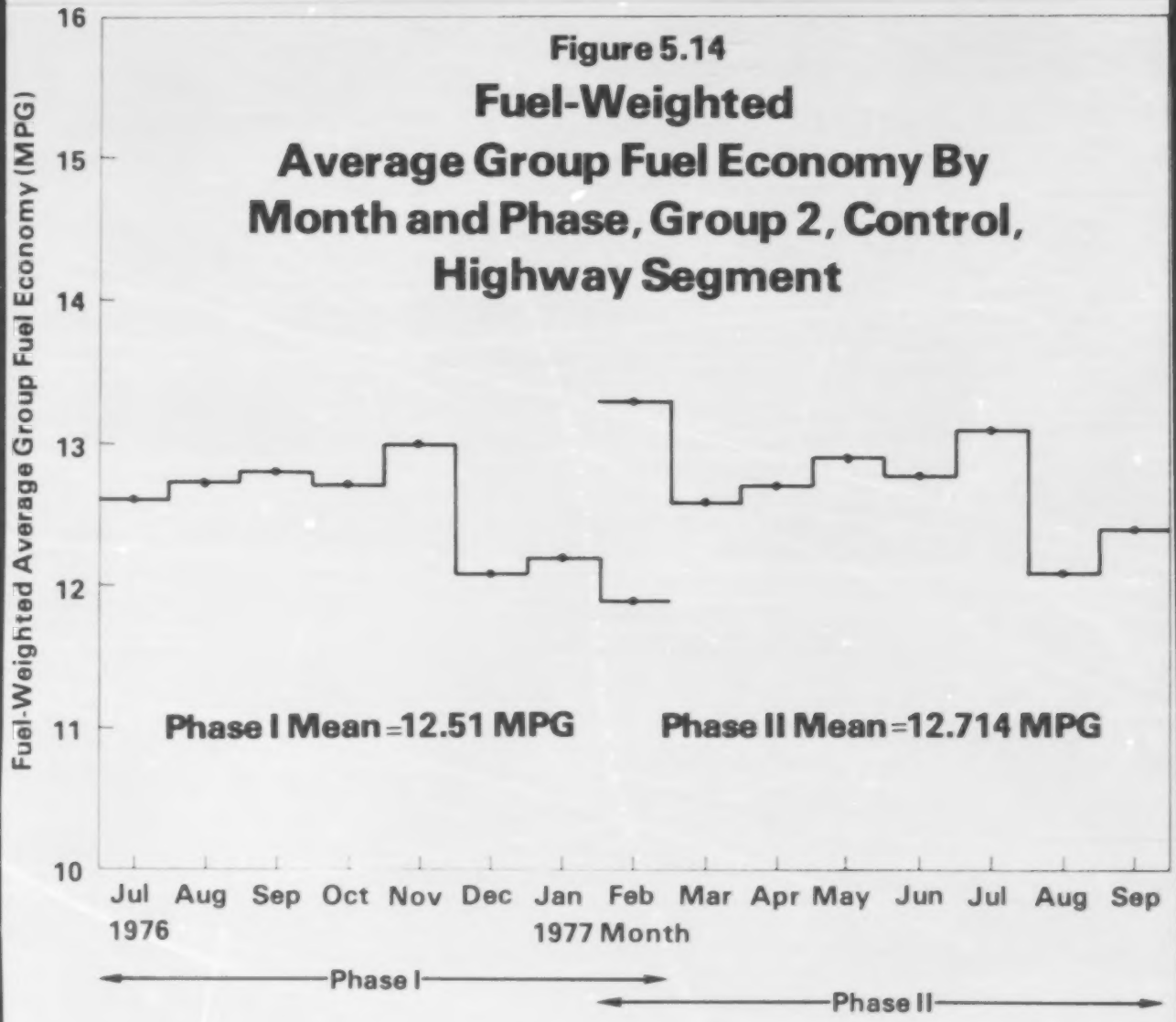


Figure 5.15

Fuel-Weighted Average Group Fuel Economy By Month and Phase, Group 3, Training, Highway Segment

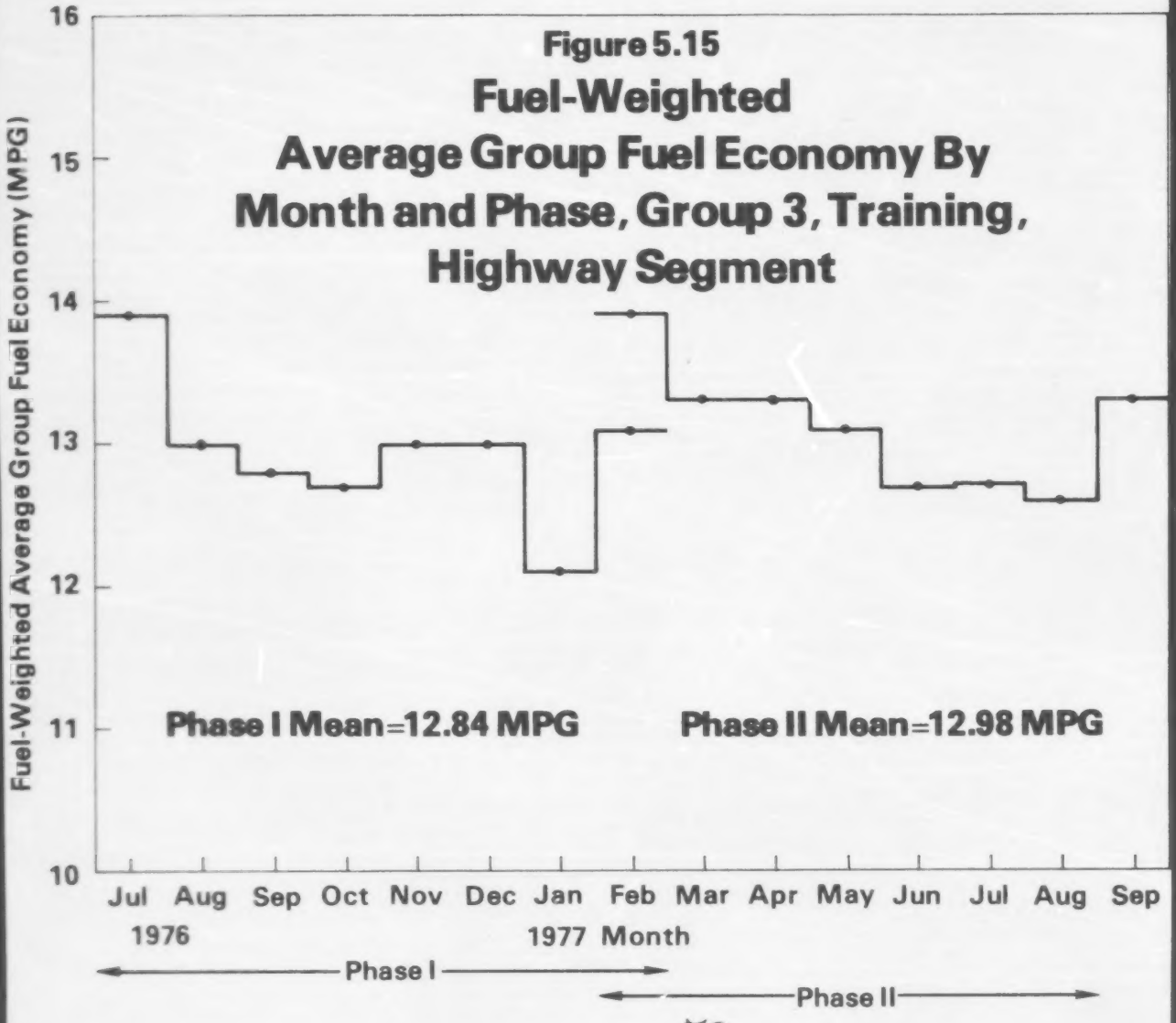


Figure 5.16

Fuel-Weighted Average Group Fuel Economy By Month and Phase, Group 4, Training Plus Dial-Type Vacuum Gauge, Highway Segment

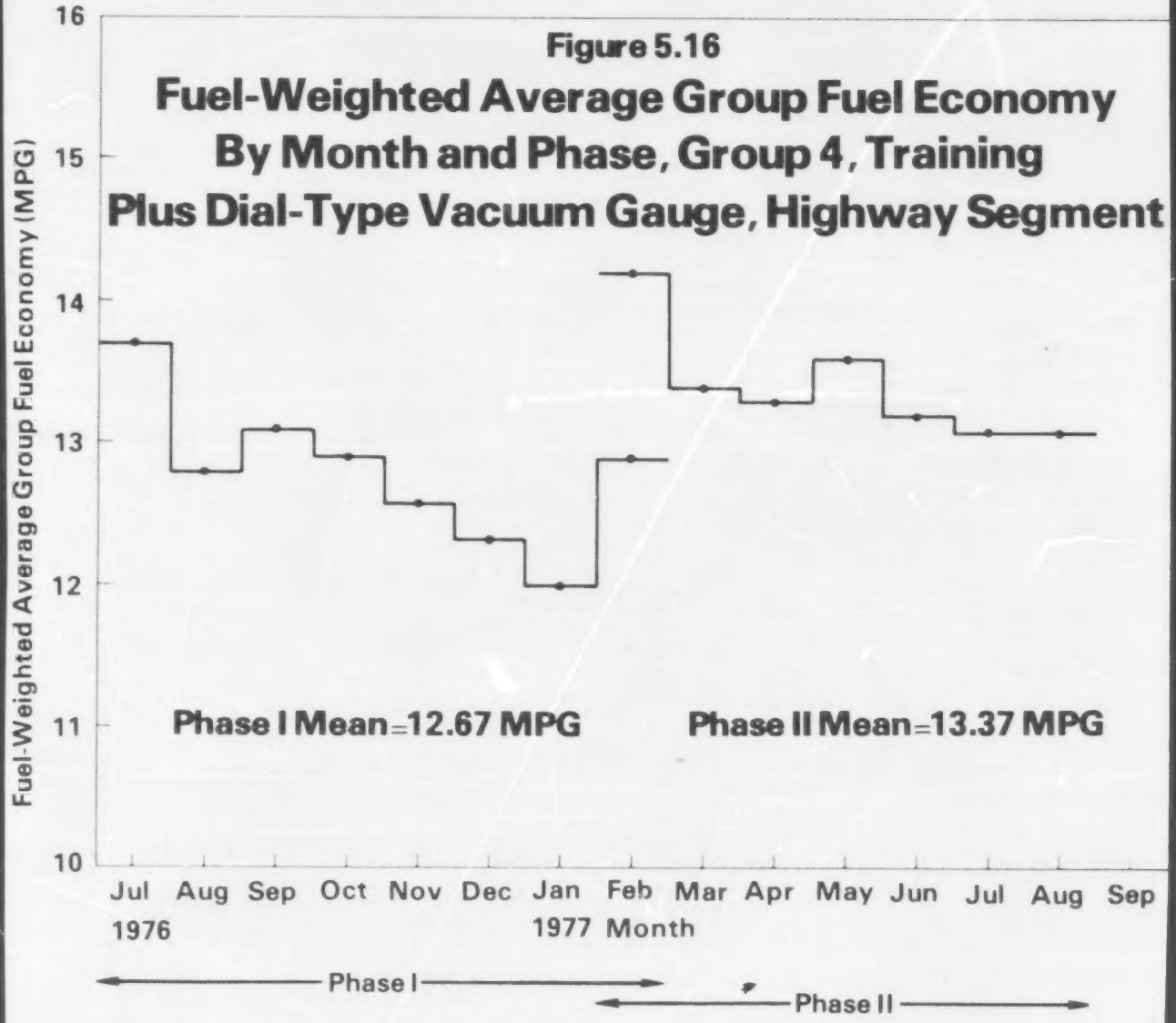


Figure 5.17

Fuel-Weighted Average Group Fuel Economy By Month and Phase, Group 5, Dial-Type Vacuum Gauge, Highway Segment

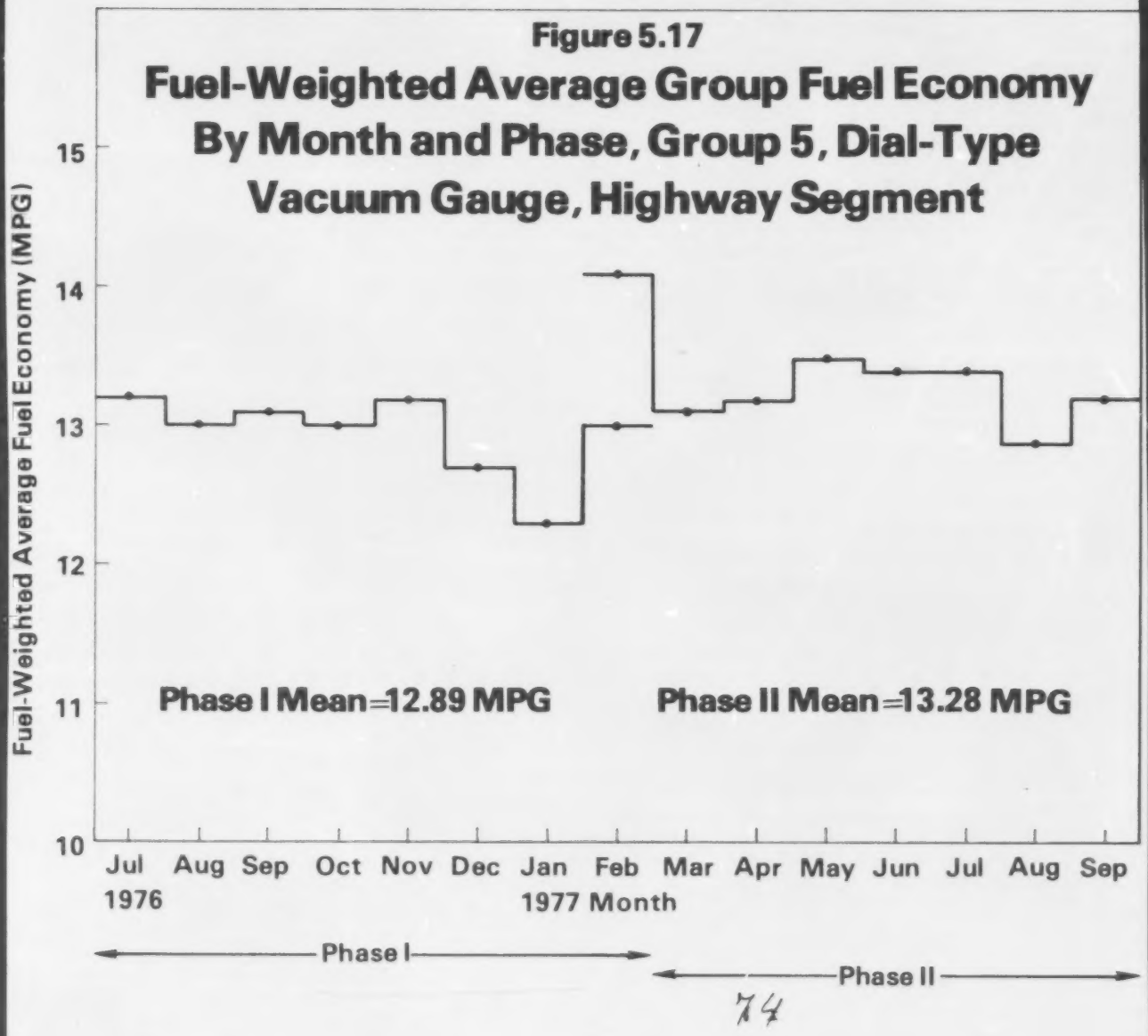
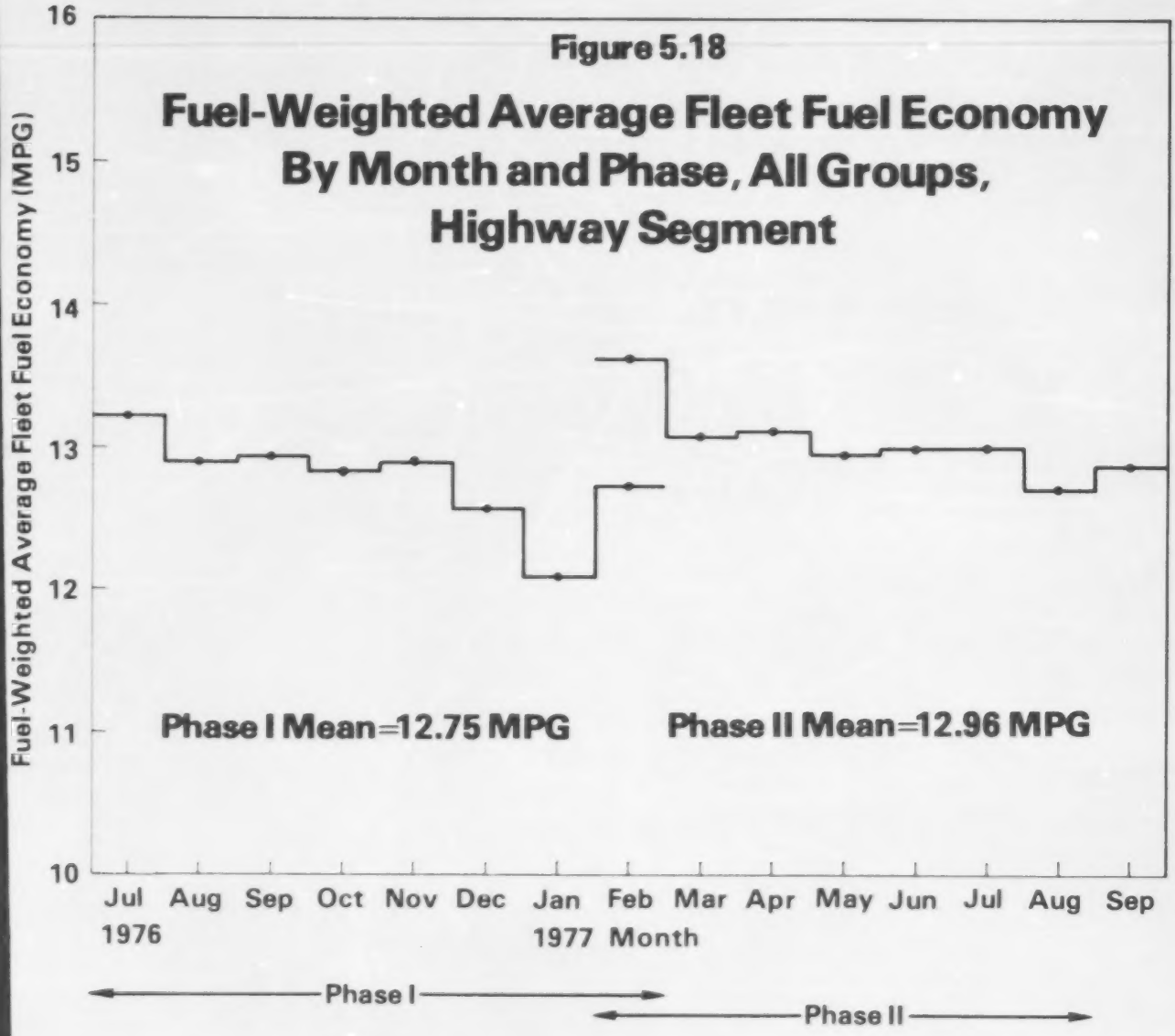


Figure 5.18

Fuel-Weighted Average Fleet Fuel Economy By Month and Phase, All Groups, Highway Segment



5.2 DRIVER QUESTIONNAIRE RESULTS

The Driver Questionnaire was administered to all highway segment participants at the end of the testing program. Participants were instructed to answer only those questions pertaining to their group's actual test participation. The questionnaire and a summary of responses are found in Appendix D. This discussion focuses upon those questionnaire responses which are most relevant to the overall test objectives.

5.2.1 Overall Assessment of Project Effectiveness

All highway segment test participants and control group members were asked to respond to this section of the questionnaire. Fifty-two percent of the respondents reported that they had changed their driving habits as a result of this program (Question 2), and 52 percent stated that they have continued to practice these changes (Question 3).

Seventy-seven percent of the participants felt that the driver aid and education test project was a worthwhile endeavor (Question 7); 18 percent of the respondents did not feel that the project was worthwhile, and five percent did not respond to this question.

Despite the fact that all possible attempts were made to eliminate extrinsic motivation as a test variable, examination of the driver questionnaire results supports the supposition that the Hawthorne effect may have been present during the test. For example, asked if they had changed their driving habits as a result of this program (Question 2), 21 percent of the drivers in the control group answered yes, compared to 60 percent of the respondents in the treatment groups.

5.2.2 Assessment of Driver Aid Devices

This section of the questionnaire was completed only by participants who had used either the dial-type vacuum gauge or the piston-type gauge. Fifty-

eight percent of the respondents using the dial-type reported that use of the gauge caused them to change the way they drive, and 36 percent of those using the piston-type reported a change in driving habits (Question 21). Sixty-six percent of drivers using the dial-type felt that the devices helped them to save fuel, and 46 percent of those who used the piston-type felt that the device was helpful in fuel conservation (Question 2).

Fifty-nine percent of drivers using the dial-type said they would like to have the device remain on their car, while 27 percent of those who had the piston-type would like to have it remain (Question 20). Twenty percent who had used the piston-type recommended that it be installed on all NTS vehicles, and 47 percent of those who had used the dial-type recommended such installation (Question 11).

Some of the attitudinal difference between drivers using the dial-type vacuum gauge and those using the piston-type gauge appears to be attributable to qualities inherent in the specific type of device which was used, rather than to vacuum gauges in general. For example, 66 percent of the drivers using the piston-type device reported that their gauges required replacement due to malfunction in the course of the test, while 4 percent of the dial-type devices malfunctioned and required replacement (Question 8).

Drivers using the dial-type device apparently had no difficulty in reading the gauge while driving. This was not the case with those drivers who used the piston-type. Fifty-four percent of piston-type users reported that the device was a distraction; 18 percent of dial-type users found the device distracting (Question 14). Drivers were asked if any "near accidents" had resulted from use of the vacuum gauge. Four of the respondents using the piston-type device reported "near accidents"; no "near accidents" were attributed

to the gauge by users of the dial-type device (Question 15). In addition, 81 percent of dial-type users felt that the vacuum gauge could be used effectively at night, while 25 percent of those with the piston-type said the gauge could be used at night (Question 24).

5.2.2 Assessment of Training Course

Test participants who had received the driver training course were asked to evaluate the impact and effectiveness of the course. The course was given a positive assessment by the majority of participants: 81 percent reported that the training course had motivated them to drive their test vehicle more fuel-efficiently; 91 percent felt that the course had also motivated them to drive their personal vehicles more fuel-efficiently; and 84 percent reported that they continue to practice fuel-conservation driving techniques learned in the training course (Questions 1, 2 and 3).

Seventy-eight percent of the course participants thought the course should be given to all NTS drivers; 14 percent did not recommend that the course be given (Question 7).

Eighty percent of those who had participated gave the training course an overall rating of "good" or "excellent"; 14 percent rated the course "fair," and only five percent gave an evaluation of "poor" (Question 8).

5.2.3 Questionnaire Summary

The results of this questionnaire indicate an overall positive response to the Driver Aid and Education Test Project. This is most evident in the assessments of the driver training course. The majority of course participants indicated that the training course was a valuable source of fuel-conservation driving techniques and a positive influence on personal driving habits.

Response to the vacuum gauge driver aids varied according to the type of vacuum gauge used in the test. The dial-type device was judged to be an effective aid to fuel-efficient driving; the piston-type gauge received a generally negative response. This difference appears to result from a combination of frequent malfunction and difficulties in reading the gauge which occurred with the piston-type device. These problems were not encountered by those participants who used the dial-type vacuum gauge.

6.0 OBSERVATIONS AND CONCLUSIONS

The following observations and conclusions, listed in order of importance, are based upon analysis of the results obtained from the Driver Aid and Education Test Project.

6.1 The results obtained in this test project provide support for the hypothesis that measurable and statistically significant increases in fuel economy can be achieved by the use of a driver energy efficiency awareness training course or a manifold vacuum gauge, or by use of the training in conjunction with the manifold vacuum gauge.

The fact that fuel economy improvements were also achieved in the untreated control groups indicates that some additional factor may have an influence on achievement of improved fuel economy. While improvements in the control groups were of smaller magnitude than those achieved in the treatment groups and are not considered statistically significant, these results indicate that sheer awareness that fuel economy is being measured may result in driving behavior which is more energy-efficient.

It is highly probable that achievement of improved fuel economy is strongly influenced by the extent to which an individual driver is motivated to save fuel. Provision of driver training and a device which provides fuel economy-related information can convert this motivation into real fuel economy improvements. However, an individual who is not motivated to save fuel may achieve no improvement, regardless of training and/or the vacuum gauge.

Peer interaction occurring within the context of a fuel economy test may provide a significant avenue for exchange of information about the objectives of the test, thus enhancing motivation. Such interaction may also result in exchange of information about methods for improving fuel economy.

6.2 The results obtained during the highway segment of the test are considered more meaningful than the urban segment data. The validity of the urban segment results is questionable for several reasons: A substantial number of vehicles were not included when analysis of variance was performed on the urban background data and the urban groups barely met the criterion for inter-group similarity; the training program presented to the urban segment drivers was different than the program used in the highway segment; and the urban sample was less than half the size of the highway segment sample.

While these deficiencies do not conclusively establish that the urban segment results are invalid, they certainly imply that the highway segment results should take precedence in making generalizations from the findings of this project.

6.3 Review of the monthly trends in group fuel economy indicates an apparent degradation of motivation or of behaviors learned in the training course for most of the treatment groups.

Depending upon the method of data aggregation used in analysis, the trend results could support several conflicting hypotheses, including the presence or absence of tune-up degradation; ambient temperature effects; or the gradual loss of learned fuel-efficient driving habits.

Since the trend data has not been subjected to statistical analysis, it is difficult to generalize from it without citing one or more exceptions.

6.4 Comparisons of the dial-type and the piston-type vacuum gauges made using the Average Group Fuel Economy method of data aggregation show that both gauges achieved similar, significant increases in fuel economy in the highway segment of the test. The urban segment results, while of

less statistical importance, indicate a clear advantage of the dial-type as compared to the piston-type gauge. Nonstatistical comparisons using the fuel-weighted method of data aggregation also indicate a strong advantage for the dial-type gauge. However, the statistical analysis conducted indicates that it is not possible to reject the hypothesis that the two gauges tested were equally effective.

6.5 The results of the driver questionnares indicate that drivers who used the dial-type gauge gave a positive overall response to the gauge about twice as often as drivers who had used the piston-type. This may be due in part to the frequent malfunctioning of the piston-type gauge throughout the test phases, and to relative difficulty in interpreting the piston movement and its lack of range.

6.6 Changes were made in the content and presentation of the training course between the highway and urban segments, making it impossible to obtain adequate measures of the relative effects of the training course with respect to driving cycle.

6.7 No group correlation was found between fuel efficiency ratio (FER), as measured by the piston-type vacuum gauge, and relative fuel economy. Thus, FER cannot be considered as a meaningful measure of fuel efficient driving techniques.

7.0 RECOMMENDATIONS

Based upon the results of this test project, the following recommendations are offered:

7.1 GENERAL RECOMMENDATIONS

7.1.1. The immediate installation of vacuum gauges alone on additional government vehicles is not recomended at this time. Use of vacuum gauges should be considered only in conjunction with a formal program to motivate and train government drivers in driver energy conservation awareness techniques, and the gauges should only be used as a driver training aid.

7.1.2. It is recommended that the Department of Energy provide continued support for research in the area of fuel-efficient driving techniques. Specifically, questions of optimum acceleration rate, braking, turning, stopping, hill climbing and hill descending should be investigated to determine the optimum techniques for use in driver energy awareness training curricula. This type of research activity has two-fold importance: the research can provide useful information for energy conservation and policy decisions using existing technology, and the interest in fuel economy exemplified by the projects will provide an example of energy conservation activities which could be pursued by other vehicle fleet operators.

7.1.3. Further analysis of the data collected during this test project is recommended, specifically in the areas of statistical methods, driver chartacteristics, vehicle characteristics, the Hawthorne effect, correlation of fuel economy with driver characteristics and job assignments, and other parameters that may assist in explaining data inconsistencies or observed anomalies.

7.1.4. It is recommended that the Federal Government consider institution of the requirement that all applicants for federal driver's licenses (both government employees and government contractors) complete training in driver energy conservation awareness prior to licensure.

7.1.5. It is recommended that a teaching textbook be prepared for vehicle fleet operators. This text should also be suitable for use by the public school system and the general public.

7.1.6. It is recommended that further research in human factors be initiated in order to develop more effective methods of providing audio/visual/tactile feedback to the vehicle driver, facilitating fuel-efficient driving behavior.

7.2 SPECIFIC RECOMMENDATIONS

7.2.1. It is recommended that the Driver Energy Conservation Awareness Training be continued, and expanded to include all Government-licensed drivers at the Nevada Test Site and the Nevada Operations Office in Las Vegas, Nevada.

7.2.2. It is recommended that all light-duty vehicles at the Nevada Test Site be instrumented with dial-type vacuum gauges, but only in conjunction with driver energy conservation awareness training.

7.2.3. It is recommended that fuel and mileage records be kept on all light-duty vehicles at the Nevada Test Site, in order to monitor the effects of driver training.

7.2.4. It is recommended that driver energy conservation awareness training methods be further refined and modified to suit the specific driving environment and types of vehicles used at the Nevada Test Site.

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GLOSSARY

Analysis of Variance: A statistical technique used to determine the extent to which each of several independent variables has contributed to changes observed in the dependent variable. In the Driver Aid and Education Test Project, analysis of variance was used to determine whether the use of a vacuum gauge driver aid and/or participation in a driver awareness training course (independent variables) contributed to changes in fuel economy (the dependent variable in this test).

Average Group - or Average Fleet - Fuel Economy The term used to represent the aggregation of fuel economy data on a group or fleet basis, which implies that each vehicle is equally important to the results, regardless of distance traveled or fuel consumed.

DOE: The United States Department of Energy.

DOE/HQ: Department of Energy Headquarters, Washington, D.C.

DOE/NV: The Nevada Operations Office of the U.S. Department of Energy.

DOT: The United States Department of Transportation.

DOT-TSC: The U.S. Department of Transportation, Transportations Systems Center (Boston, Mass.).

Driver Aid Device: Any mechanical or electronic device which is used to provide the driver with information about engine or vehicle peformance related, either directly or indirectly, to fuel economy. Driver aid device as used in this report refers only to the manifold vacuum gauges used in the test project.

Dynamometer: An apparatus for measuring the mechanical power output of an engine or motor vehicle.

FER: Fuel Efficiency Ratio. Defined as the number of low-vacuum events

divided by the number of engine starts observed during a given driving sequence, as measured by the piston-type vacuum gauge used in this project.

Fuel-Weighted Average Group - or Average Fleet - Fuel Economy: The term used to represent the aggregation of fuel economy data on a group or fleet basis, which implies that each gallon of fuel consumed is equally important to the results regardless of which vehicle consumes the fuel. Hawthorne Effect: The term used to refer to the observed fact that when human subjects are in a research project they may change their normal behavior because they perceive that this behavior is being tested or evaluated. These changes in behavior may either enhance or detract from the real effects of a specific treatment, thus confounding the results.

Light-duty Vehicle: Any vehicle with a gross vehicle weight (GVW) rating of less than 6,000 pounds.

Low-Vacuum Event Counter: A feature of the piston-type vacuum gauge used in this project. It records the number of times that the engine manifold vacuum drops below a set value.

Manifold Vacuum Gauge: A device which measures and displays the value of engine intake manifold vacuum. High manifold vacuum (i.e., low absolute manifold pressure) is generally associated with low power output and high fuel economy.

MPG: Miles Per Gallon. The number of miles traveled per gallon of gasoline consumed.

MPH: Miles Per Hour. The number of miles traveled in one hour.

NTS: The Nevada Test Site. A Federal reserve operated by the United States Department of Energy, approximately 65 miles Northwest of Las Vegas, Nevada.

Odometer: An instrument for measuring the distance traveled by a vehicle.

Random Variation: The opposite of a "significant" variation, this is the term applied to results which have shown upon statistical analysis to have a random probability of five percent or more, indicating that the result in question could have occurred by chance, rather than in response to a specific treatment.

REECO: Reynolds Electric and Engineering Company, Inc., an NTS contractor.

Significance Level: A term used to indicate the probability that a given result did not occur by chance. For example, a significance level of .05 indicates a 95 percent probability that the result in question did not occur by chance.

Statistical Significance: When test results are termed "statistically significant," this means that the data have been subjected to statistical techniques which permit the researcher to reject the hypothesis (with a 5 percent or less chance of being wrong) that these results have come about by chance.

Significance Test: The mathematical procedure used to determine the probability that a given result occurred by chance.

TEC: The Division of Transportation Energy Conservation, a division within the United States Department of Energy.

APPENDIX A

TEST VEHICLE CHARACTERISTICS AND LOG SHEETS

Figure A-1 -- Typical Vehicle Characterization and Checkout Sheet*

FUEL ECONOMY TEST - LIGHT DUTY VEHICLES
TEST VEHICLE SPECIFICATIONS AND PREPARATION

SPECIFICATION LIST

Date_____
Car No._____
Year and Make_____
Model & Body_____
Vehicle I.D. No._____
Production_____ Other_____
Engine_____ Disp._____
Net H.P._____ Comp. Ratio.___
Engine No._____
Carb. Type & No._____
Distributor No._____
Exhaust System Type_____
Transmission_____
Rear Axle Type & Ratio_____
Brakes - Front_____Rear_____
Steering_____
Tire Make_____Size_____
Load Range____Type_____
Cold Inflation - Tire Pressure
LF_____RF_____
LR_____RR_____
Test Weight_____
Tires must have a minimum of
100 mile (160 km) Break-in

CHECKLIST

_____Engine Oil Level
_____Coolant Level
_____Transmission Fluid Level
_____Belts and Hoses - Tight
_____Emission Controls - Functional
_____Choke Operations
_____Throttle Operations
_____Pump and Nozzles - No leaks
_____Ignition Wires - Tight
_____Brake Drag - Not Excessive
_____Transmission Operation
_____Tire Pressure and Condition
_____Engine Tune
_____Ignition-Timing_____
_____Idle RPM____Idle Co._____
_____Ignition Point Dwell_____
_____Wheel Alignment
_____Air Cleaner - Clean
_____A/C Compressor Lead - Removed
_____No Fuel Leaks
_____Manifold Head Valve
_____Fan Clutch

CHECK OPTIONAL EQUIPMENT

_____Power Disc. Brakes
_____Power Drum Brakes
_____Power Steering
_____Air Conditioning
_____Radio
_____Power Seats
_____Power Windows
_____Power Door Locks
_____

ODOMETER ACCURACY

Actual_____Reads_____

COMMENTS:_____

_____

_____

_____

_____

CAR CHECKED BY:_____

DATE:_____

TEST FUEL SPECIFICATIONS

Fuel Type and Grade_____
Gravity (API or Specific)_____
Reid Vapor Pressure____PSI (Pa)

*Completed at the beginning of Phases I and II

Figure A-2 -- Typical Vehicle Operating Profile Characterization Sheet*

VEHICLE PROFILE

Month _____ Vehicle Number _____

PLEASE CIRCLE BEST ESTIMATE

1. Number of drivers assigned t this vehicle.

   1 2 3 or more

2. Average number of passengers (excluding driver).

   0 1 2 3 or more

3. Major driving pattern:

   a. Slow speed (15 to 35 mph) stop and go

   b. Moderate speed (25 to 45 mph) few stops

   c. High speed (40 mph and up) few speed changes

4. Was air conditioning used (percent of time)?

   0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

5. Were heavy loads (in excess of 100 lbs.) hauled (percent of time)?

   0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

*Submit this vehicle profile sheet to your Administrative Office within 4 working days following the end of each month.

Table A-1 – Highway Test Segment

GROUP ASSIGNMENTS BY VEHICLE CHARACTERISTICS

Characteristics	Group 1 (Piston Vacuum Gauge)	Group 2 (Control)	Group 3 (Training)	Group 4 (Training Plus Dial Vacuum Gauge)	Group 5 (Dial Vacuum Gauge)	Total
Vehicle Size						
Compact	11	10	10	11	11	53
Intermediate and Full	8	8	10	9	7	42
Pick-up Truck	45	45	48	45	48	231
Transmission Type						
Automatic	61	60	63	62	62	308
Manual	3	3	5	3	4	18
Air Conditioning Option						
Air	54	52	54	54	53	267
No Air	10	11	14	11	13	59

Table A-2 – Tally of Highway Segment Vehicles by Characteristics

VEHICLE TYPE	TRANSMISSION TYPE	INSTALLED AIR CONDITIONING	NUMBER OF VEHICLES
Compact	Automatic	Yes	53
Intermediate and Full Size	Automatic	No	1
Intermediate and Full Size	Automatic	Yes	41
Pick-up Truck	Automatic	No	44
Pick-up Truck	Automatic	Yes	169
Pick-up Truck	Manual	No	14
Pick-up Truck	Manual	Yes	4
		TOTAL	326

Table A-3 – Urban Segment

GROUP ASSIGNMENTS BY VEHICLE CHARACTERISTICS

Characteristics	Group 1 (Piston Vacuum Gauge)	Group 2 (Control)	Group 3 (Training)	Group 4 (Training Plus Dial Vacuum Gauge)	Group 5 (Dial Vacuum Gauge)	Total
Vehicle Size						
Compact	15	15	15	15	15	74
Intermediate and Full	3	3	3	3	2	14
1/2 ton Pick-up truck	7	7	6	8	7	35
3/4 ton and 1 ton Pick-up truck	4	4	5	3	4	20
Transmission Type						
Automatic	27	27	27	27	25	133
Manual	2	2	2	2	2	10
TOTALS	29	29	29	29	27	143

FIGURE A-3

SAMPLE

TEST VEHICLE DRIVER'S LOG*

_____
Month

_____
Vehicle No.

Gallons	Odometer Reading	Date	Station	Driver Initials
.	.			
.	.			
.	.			
.	.			
.	.			
.	.			
.	.			
.	.			
.	.			
.	.			
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.	.			
.	.			
.	.			

*Submic this log sheet to your Administrative Office within 4 working days following the end of each month.

FIGURE A-4

S A M P L E

TEST VEHICLE LOG SHEET

VEHICLE NO.	GALLONS	ODOMETER READING	DATE	STATION
	.	.		
	.	.		
	.	.		
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APPENDIX B

TEST SITE CHARACTERISTICS

APPENDIX B

TEST SITE CHARACTERISTICS

The highway segment of the test was conducted at the Nevada Test Site, a Federal facility operated by the Department of Energy approximately 65 miles northwest of Las Vegas, Nevada. (Figure B-1.) The test site encompasses a contiguous area of approximately 1400 square miles, a major portion of which consists of flat or rolling desert area, but some of the site is mountainous terrain with extreme road grades (Figure B-2). All main roads within the NTS are two or four lane asphalt-paved and in good to-excellent condition. Typical driving within the area consists of trips of 10 to 30 miles, which is similar to most highway travel on public roads.

Local weather is typical of the surrounding desert: usually dry, with infrequent, intense rainfall, winter snow at the higher altitudes, and substantial changes in diurnal temperature. Average annual precipitation ranges from 4 to 12 inches, depending upon elevation. Annual temperatures range from 0°F (-18°C) in winter to 115°F (45°C) during the summer. Mean temperatures for the project period are presented in Figures B-3 through B-5.

Wind speed at the site is usually low because most of the area is protected by mountains. Prevailing winds are from the northeast, with an average speed of 7.2 mph. Wind speed is higher in the unprotected areas of the reserve, and wind-blown sand is a frequent phenomenon in these areas.

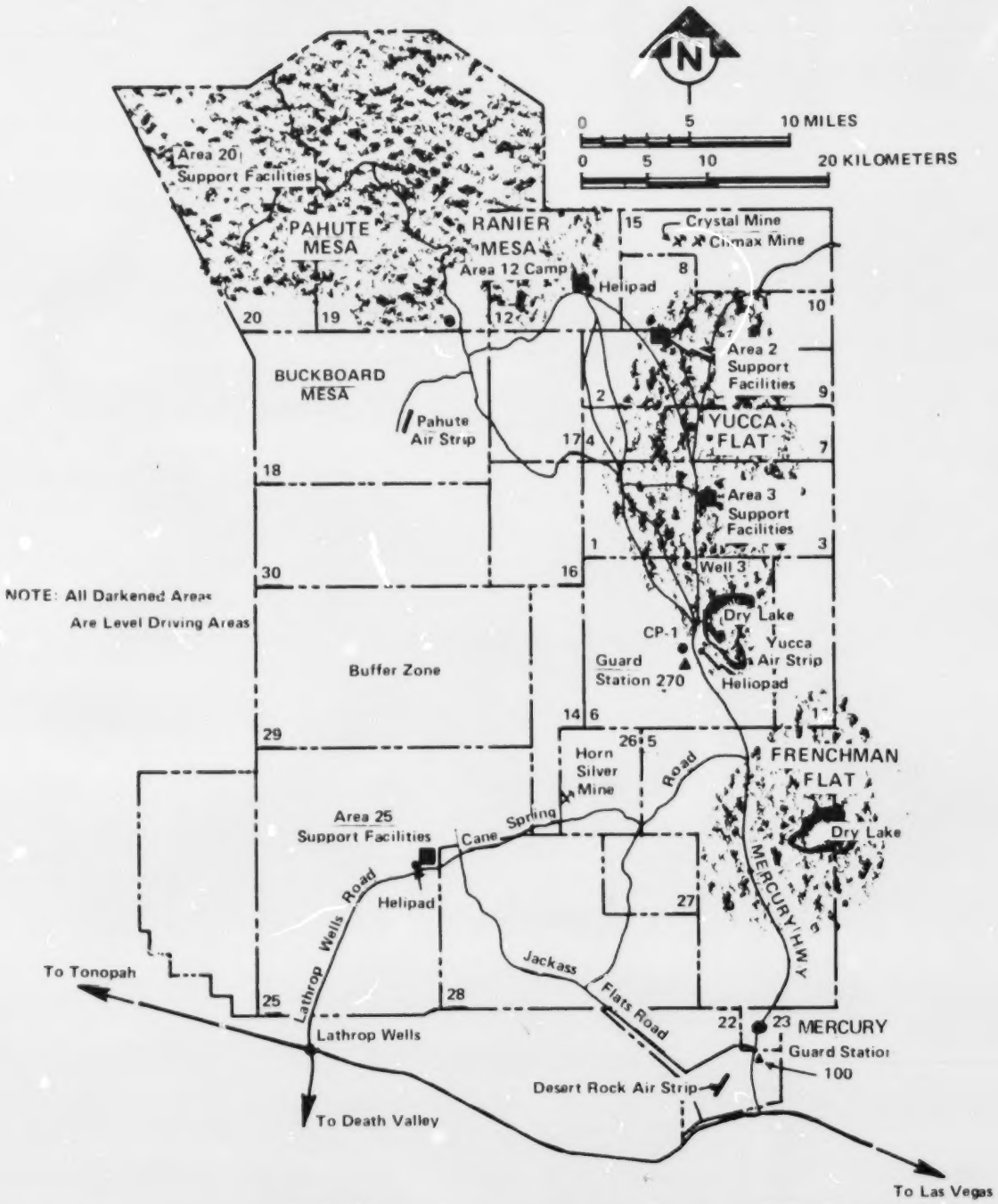
The urban test segment was conducted within the environs of Las Vegas, Nevada. This area is representative of a moderately congested urban driving environment, with traffic concentration occurring during morning, noon and evening rush hours. Las Vegas is more compact than most cities because

suitable building and living space is determined by available water supply. Consequently, almost all of the inhabitants live and work within the city limits. Driving in this segment was typically the short, in-city trips of the Clark County inspectors, managers, and supervisors.

Weather conditions in Las Vegas are similar to those at the Nevada Test Site, although average temperatures are somewhat higher and diurnal extremes smaller. Due to the lack of protective surrounding mountains, wind speeds are greater than at the NTS. Prevailing winds are from the southwest, with an average speed of 9 mph. Rainfall in the city is low, infrequent, and often intense. No measurable snowfall occurred in the area during the test period.

Figures B-6 and B-7, respectively, illustrate typical driving environments at the highway and urban test sites.

Fig. B-1 Nevada Test Site



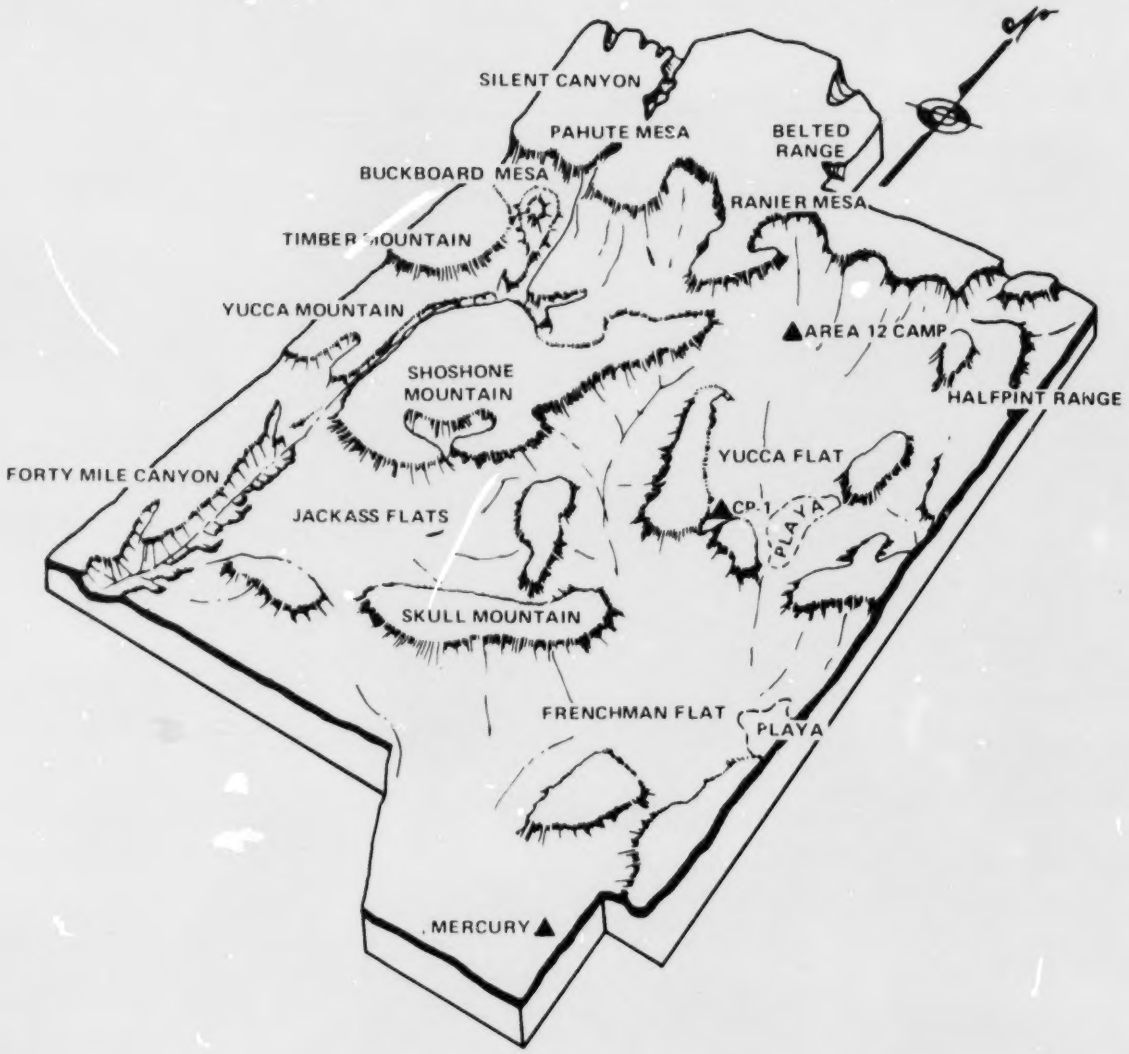


Fig B-2
TYPOGRAPHY OF THE NEVADA TEST SITE

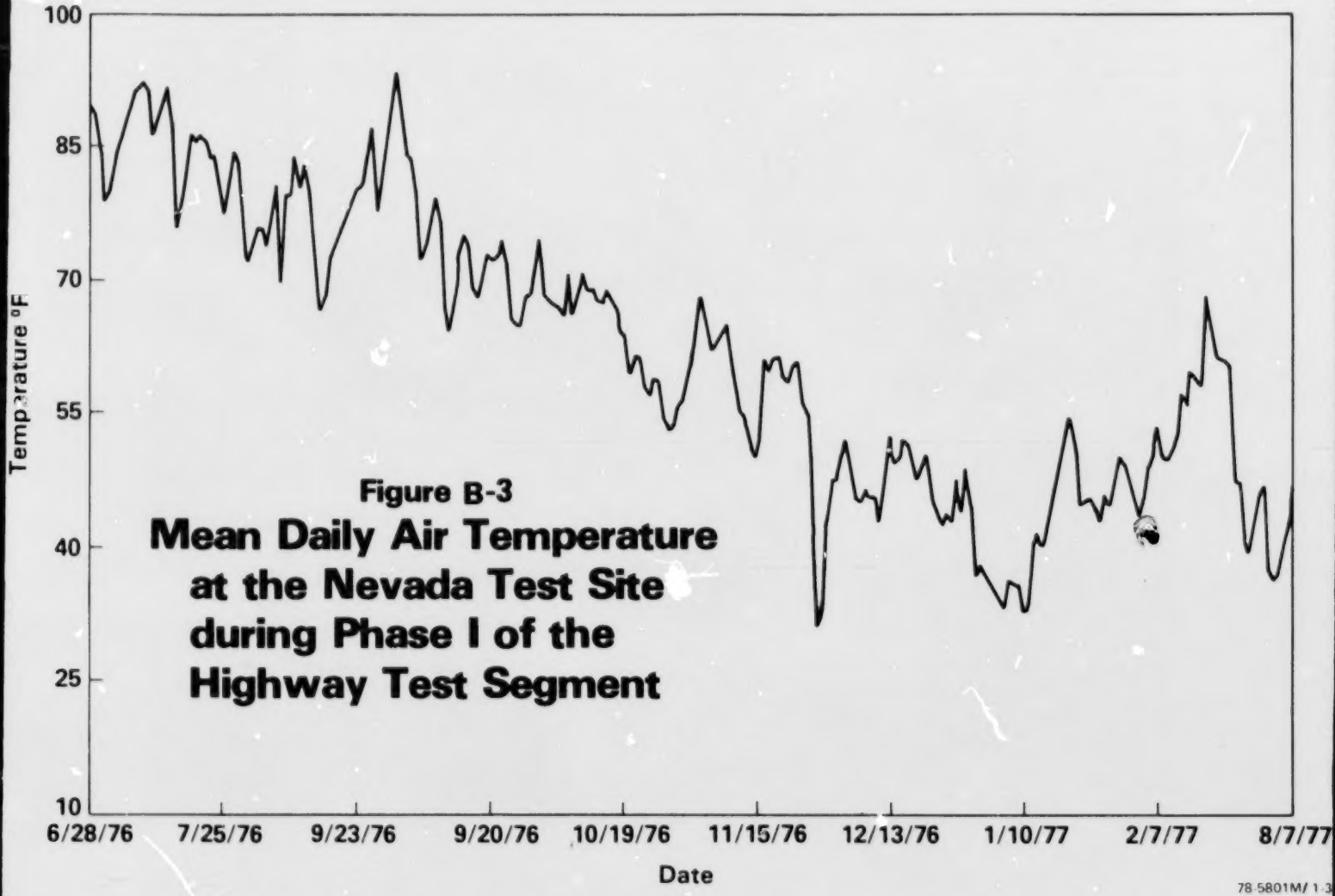


Figure B-3

Mean Daily Air Temperature at the Nevada Test Site during Phase I of the Highway Test Segment

78 5801M/ 1 3

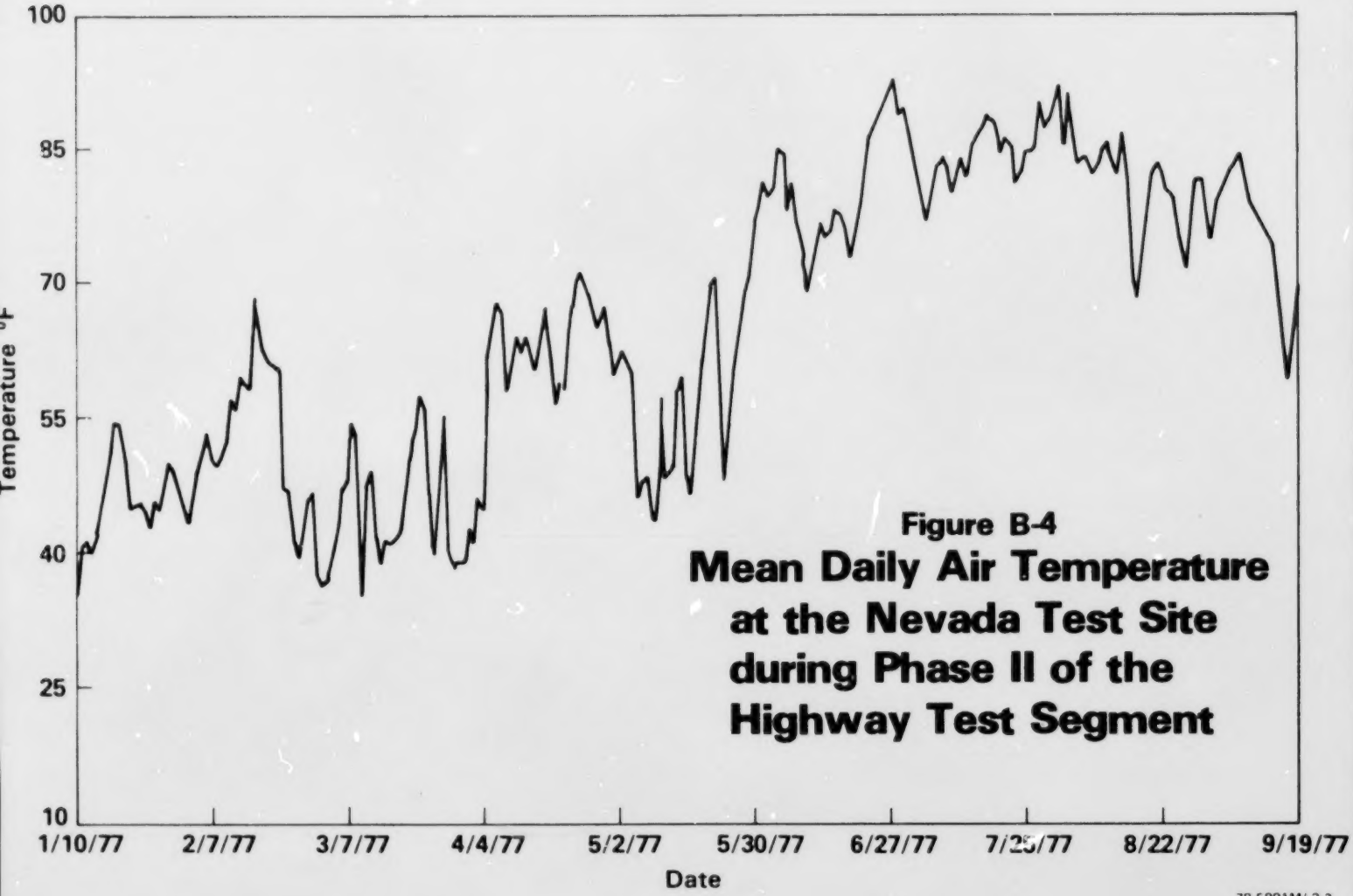


Figure B-4

Mean Daily Air Temperature at the Nevada Test Site during Phase II of the Highway Test Segment

78-5801M-2-3

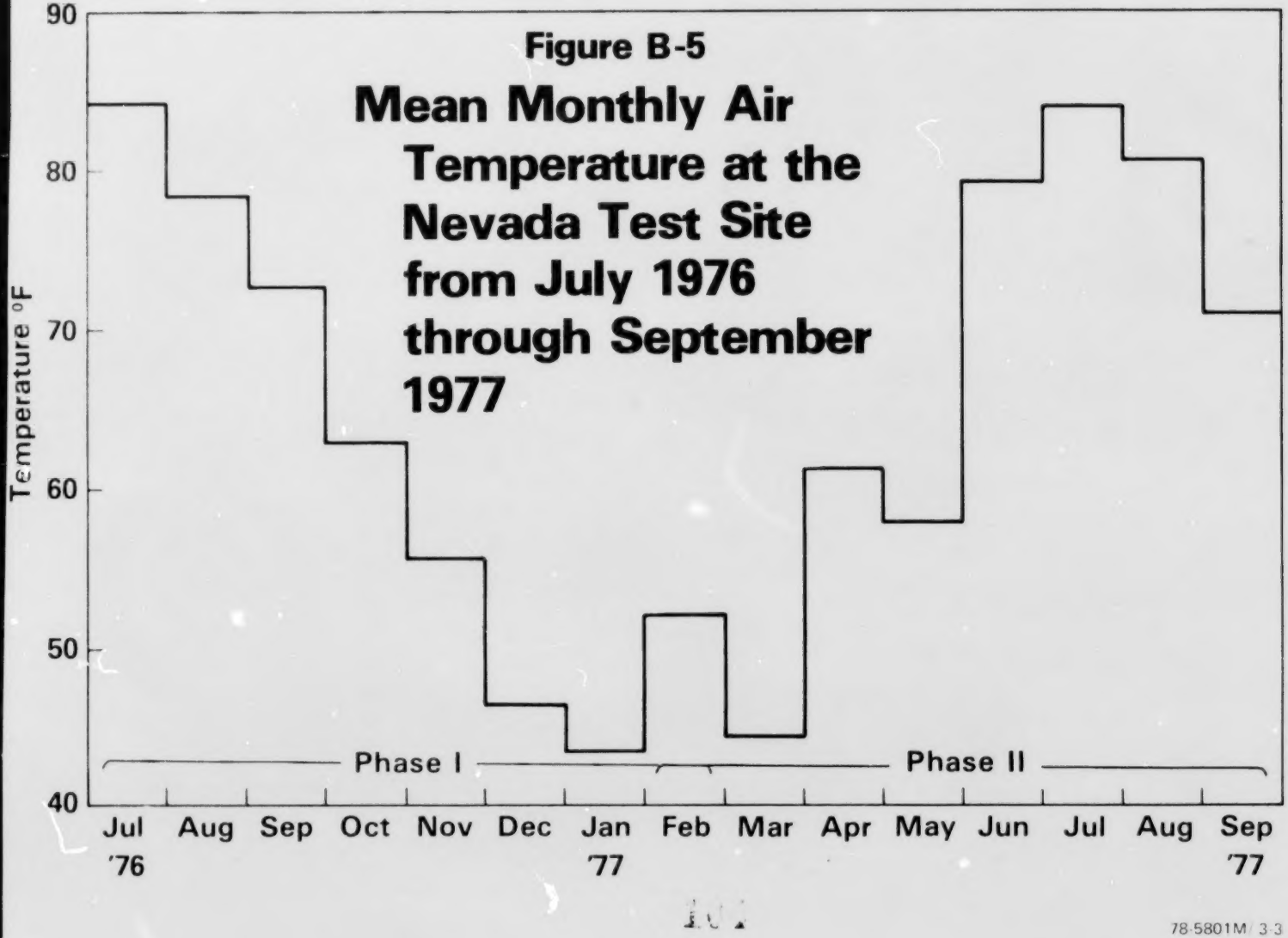


Figure B-5

Mean Monthly Air Temperature at the Nevada Test Site from July 1976 through September 1977

78-5801M/3-3

Figure B-6. Typical Highway Test Segment Driving Environment at the Nevada Test Site

Figure B-7. Typical Urban Test Segment Driving Environment in Las Vegas, Nevada

APPENDIX C

DRIVER TRAINING METHODS AND MATERIALS

SUMMARY OF DRIVER TRAINING METHODS AND MATERIALS

BACKGROUND

All urban and highway segment test drivers in Group 3 (training only) and Group 4 (training plus dial vacuum gauge) attended a training course designed to educate them in fuel-efficient driving techniques. The training course was developed by REECO training personnel at the Nevada Test Site with the assistance of FEA personnel and Mr. Robert Allen (McDonnell Douglas Company), an expert in highway vehicle fuel conservation techniques.

Development of the training course required approximately five months (September, 1976, to January, 1977). A workshop and pilot demonstration of the course were conducted at DOE offices in Germantown, Maryland, in early January, 1977. Approximately 20 participants from industry and Federal, state and local governments attended. A refinement of the course was based upon this workshop/demonstration, incorporating the suggestions supplied by participants.

COURSE DESCRIPTION

The training course presented to the highway segment participants was a four hour program. Groups of 20 students were given a two hour classroom presentation which included an introduction describing only their part of the test, description of various fuel-saving driving techniques, class participation in ranking these techniques, and two films demonstrating the effects of both efficient and inefficient driving techniques. Each student then spent approximately two hours in an instrumented vehicle. Part of this time was spent as a passenger, observing the responses of the instruments, and the reminder was spent actually driving the vehicle. Following the in-vehicle

program, the students attended a half-hour session, at which time the course was summarized, results of in-vehicle tests were presented, and each student was requested to complete an evaluation of the course.

The urban segment training course was slightly modified from the highway segment version described above. The course was shortened to three hours, class size averaged nine students, and a pre-instruction, in-vehicle test was added to the presentation.

DETAILS OF THE TRAINING COURSE

1. Slides on Fuel-Efficient Driving Techniques and Energy Conservation Awareness

Approximately 60 slides were shown and discussed during the classroom demonstration. Slide topics included air and tire drag, cold starts, acceleration, engine and vehicle size, vehicle speed effects, carburetor function, effects of engine wear, viscosity of lubricants, and types of instruments and gauges available. Additional slide topics included the energy crisis, maintenance methods, and other subjects of related interest. This presentation was designed to establish awareness of the energy crisis and to promote methods which each student could use to improve his vehicle fuel economy.

2. Group Participation

Each class was divided into small working groups. Every group received a packet of 50 cards, each of which expressed a fuel conservation idea. The groups were instructed to discuss each idea and arrange the cards in order of relative importance according to group consensus. Each group's ranking was then discussed with the entire class. This method was used to stimulate group discussion and to assist the students in formulating questions.

3. Films

Two films were used in the highway segment training course: "Featherfoot," by Honeywell, Inc. (30 minutes) was presented at the beginning of the course, and "Saving Energy on the Road," by Ramsgate Films (15 minutes) was shown during the final session. Subsequent review of the training course indicated that the two films used in the highway segment were somewhat redundant. Therefore, only "Saving Energy on the Road" was presented in the urban segment of the course.

4. Carburetor Model

A Rochester four barrel carburetor was used as a teaching aid during the course to illustrate the relationship between accelerator pedal movement and carburetor response. The action of the choke, accelerator pump, and power valve were also demonstrated.

5. Instrumented Vehicles and In-Vehicle Instruction

Three automobiles were instrumented for the training course. A dial vacuum gauge, a linear vacuum gauge, and a fuel and distance totalizer were installed in each training vehicle (Figures C-1 through C-3). During in-vehicle training, the student driver and the student passengers could observe the instruments function. Each student was instructed to drive "normally" over a specified course, during which fuel consumed and distance traveled were measured. A driving instructor then demonstrated fuel-efficient driving techniques. Following the classroom instruction, each of the students was allowed to drive the vehicle again over the same course. Fuel and distance were measured and compared to the results obtained prior to classroom instructions. Each driver was told how his fuel economy had changed and the reasons for his good (or poor) performance were explained. Diagrams of the highway and urban driving cycles are shown in Figures C-4 and C-5.

6. Training Course Evaluation

After completion of classroom and in-vehicle instruction, each student was asked to evaluate the course and to offer recommendations for its improvement.

7. Outcome of Training Sessions

The fuel economy achieved by each training course participant was measured during the in-vehicle training. The highway segment participants experienced an average improvement of 9.9 percent. The urban segment participants experienced an average of 4.6 percent improvement. The lower relative improvement of the urban groups may be due, at least in part, to an observed increase in urban traffic congestion which occurred during the post-training, in-vehicle tests.

Figure C-1. Typical Dial-Type Manifold Vacuum Gauge Installation. (Gauges Used In Test Were Not Numerically Graduated)

Figure C-2. Typical Piston-Type Manifold Vacuum Gauge Installation

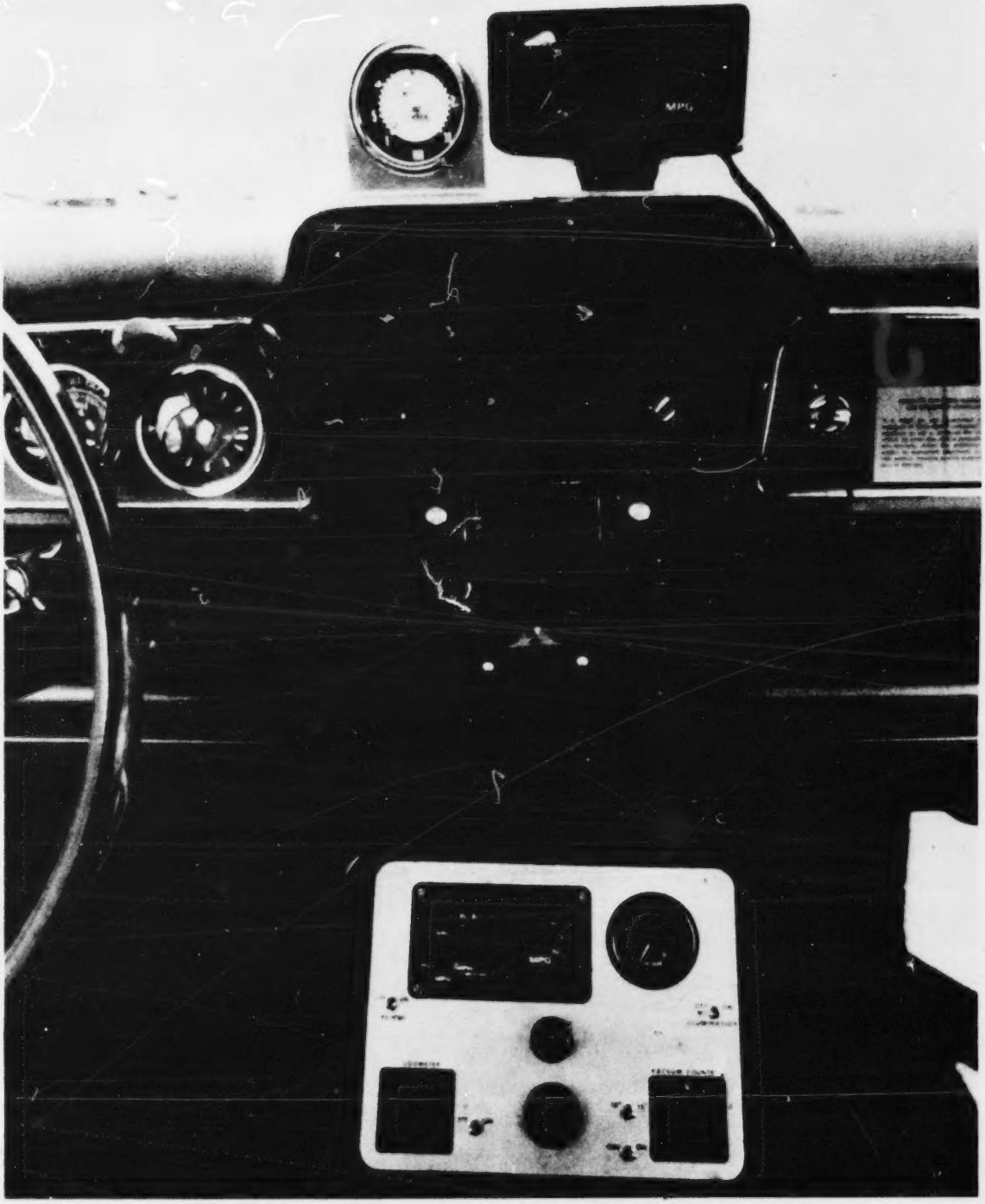


Figure C-3. Typical Instrumentation of Training Course Instructor's Vehicle

Fig. C-4 Highway Test Segment Driving Route for Training Course

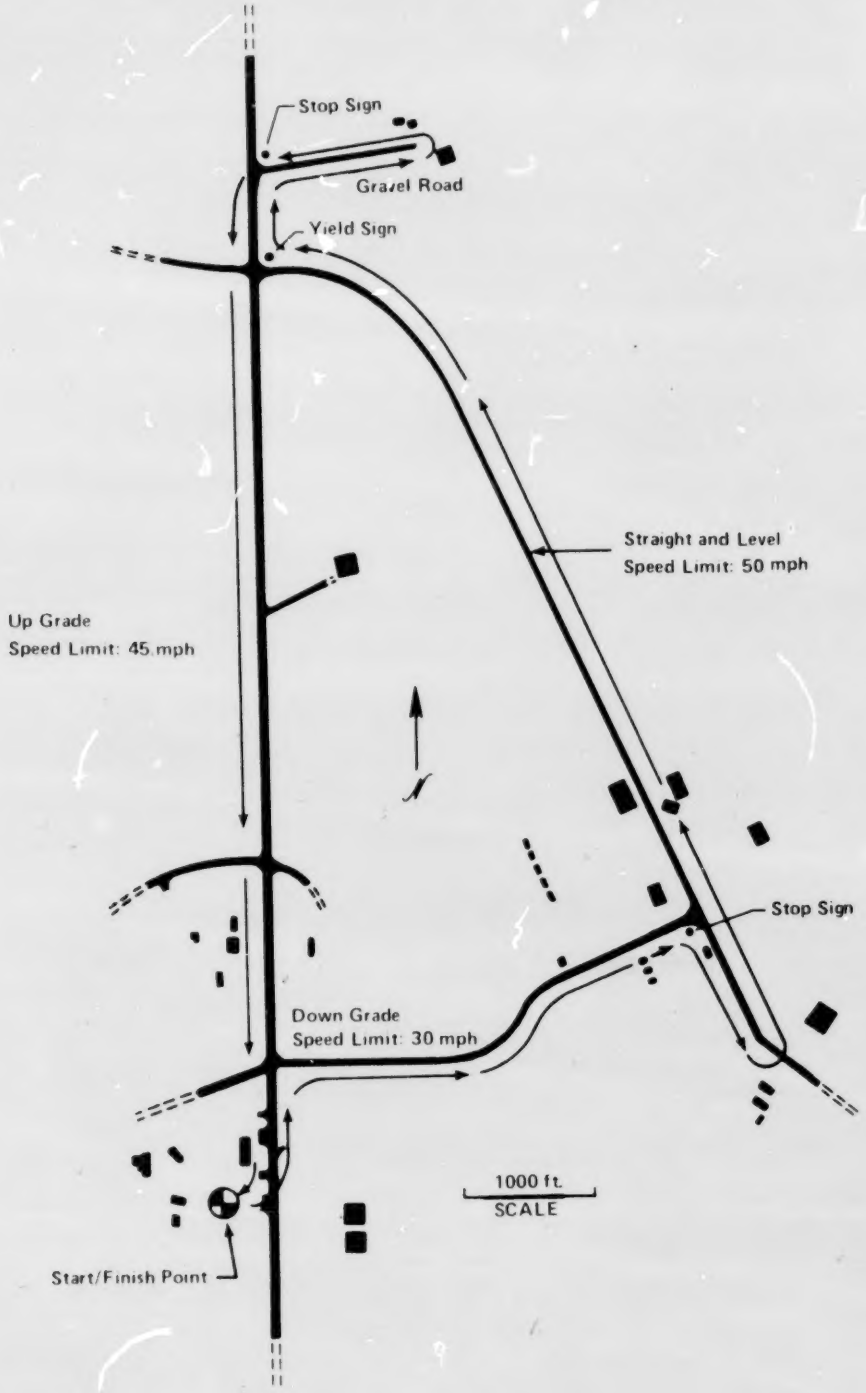
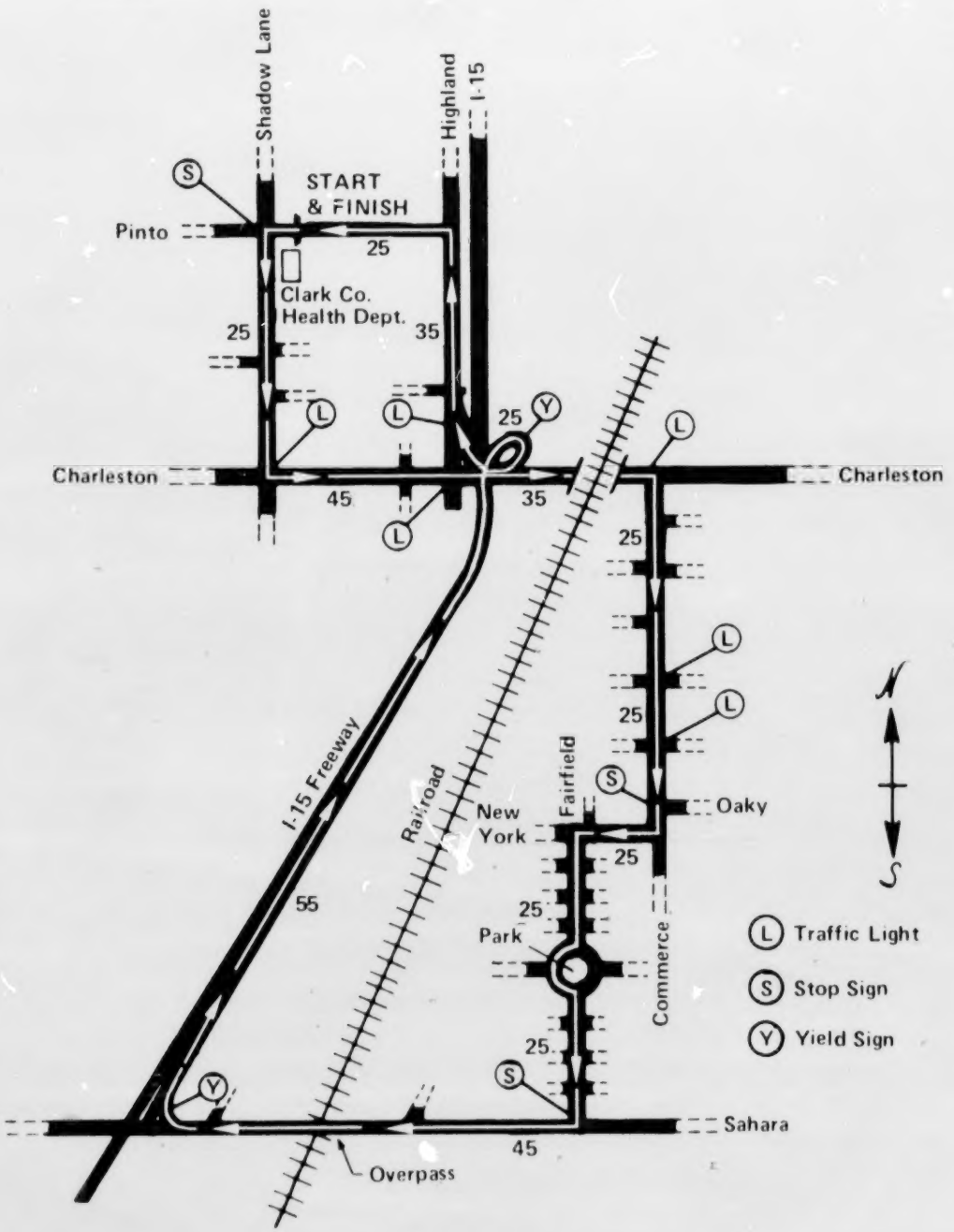


Fig. C-5 Urban Test Segment Driving Route for Training Course



APPENDIX D

DRIVER AID AND EDUCATION TEST PROJECT
TEST DRIVER QUESTIONNAIRE RESULTS

APPENDIX D

DRIVER AID AND EDUCATION TEST PROJECT

DRIVER QUESTIONNAIRE RESULTS [1]

Section A

	CONTROL GROUP (n=57)[2]			TREATMENT GROUPS (n=222)[2]		
	Yes #(%)	No #(%)	No Response #(%)	Yes #(%)	No #(%)	No Response #(%)
Q.1. Did you keep a record of your mpg?	31(54)	26(46)	0	126(57)	95(43)	1(1)
Q.2. Did you change your driving habits as a result of this program?	12(21)	45(79)	0	134(60)	88(40)	0
Q.3. Do you continue to practice these changes?	14(25)	19(33)	24(42)	131(59)	58(26)	57(26)
Q.4. Did the lack of information on your mpg performance affect your attitude toward the project?	12(21)	45(79)	0	28(13)	189(85)	5(2)
Q.6. Do you believe that the United States is currently experiencing an energy crisis?	46(81)	9(16)	2(4)	159(72)	54(24)	11(5)
Q.7. Do you feel that this project was worthwhile?	42(74)	8(14)	7(12)	174(78)	41(18)	14(6)

[1] Some of the questions are out of sequence due to formating considerations.

[2] The base N's from which the percentages are calculated are not equal to the total number of participants in each of the 5 test groups. The n's used in this table reflect the total number of group members from whom this data had been collected at the time this report was presented. However, scrutiny of those later responses which are not included shows no significant deviation from the results presented here.

Percentages shown were rounded to the nearest whole number.

Section A – Cont'd

	CONTROL GROUP (n=57)			TREATMENT GROUPS (n=222)		
	Yes #(%)	No #(%)	No Response #(%)	Yes #(%)	No #(%)	No Response #(%)
Q.8. Would you have worked harder at conserving fuel if you had been paid for the fuel savings?	14(25)	38(67)	5(9)	60(27)	154(69)	13(6)

Q.5. How many people, to your knowledge, drove your vehicle on a routine basis?

Control Group: 1 = 30; 2 = 13; 3 = 6; 4 = 0; 5 = 5; No response = 2

Treatment Group: 1 = 101; 2 = 57; 3 = 40; 4 = 11; 5 = 12; No response = 1

Section B (n=185)

		Yes #(%)	No #(%)	No Response #(%)
Q. 1. Do you feel you understand how to use this device to help you drive more fuel efficiently?		150(81)	17(9)	18(10)
Q. 2. Do you feel that the device helped you save fuel?	VacTach	26	27	
	Motorminder	74 } 100(54)	38 } 65(35)	20(11)
Q. 3. Did the written instructions (VacTach only) adequately explain the use of the device?		45(25)	6(3)	134(72)
Q. 5. Did you do anything during the test period to deactivate the device?		2(1)	165(89)	18(10)
Q. 6. Did you attempt to drive so as to minimize the number of violations (VacTach only)?		44(24)	10(5)	131(71)
Q. 7. Do you feel your device operated properly during the test?	VacTach	23	30	
	Motorminder	98 } 121(65)	11 } 41(22)	23(12)
Q. 8. Was your device replaced at sometime during the test because it malfunctioned?	VacTach	37	18	
	Motorminder	5 } 42(23)	105 } 123(66)	20(11)
Q. 9. Would some additional instruction on the use of the device have been useful?		36(19)	130(70)	19(10)
Q.10. Did you drive in second gear more often after the device was installed to keep from receiving violations (VacTach) or registering low vacuum reading?		23(12)	99(54)	63(34)

Section B – Cont'd

		Yes #(%)	No #(%)	No Response #(%)
Q.11. Would you recommend that this style of vacuum gauge be installed in all Nevada Test Site light vehicles?	VacTach Motorminder	11 53 } 64(35)	44 54 } 98(53)	23(12)
Q.12. Have you installed a vacuum gauge on your personal vehicle?		15(8)	149(81)	21(11)
Q.14. Was the device a distraction?	VacTach Motorminder	30 20 } 50(27)	24 92 } 116(63)	19(10)
Q.15. Did the device cause any near accidents?	VacTach Motorminder	4 0 } 4(2)	51 113 } 164(89)	17(9)
Q.20. Would you like to have this device remain on your car?	VacTach Motorminder	15 67 } 82(44)	37 34 } 71(38)	32(17)
Q.21. Has the use of the device caused you to change the way you drive?	VacTach Motorminder	20 65 } 85(46)	35 47 } 82(44)	18(10)
Q.24. Has practice using the device decreased the effort required to use it?	VacTach Motorminder	14 91 } 105(57)	35 18 } 53(29)	27(15)

Section B – Cont'd

Q. 4. How much would you be willing to pay for a device identical or similar to the one installed on your vehicle?

$0: 47(25%)	$2: 4(2%)	$5: 29(16)	$10: 24(13%)
$15: 12(6%)	$20: 9(5%)	$50: 1(1%)	No Response: 59(32%)

Q.13. When was the device useful?

Accelerating: 77(42%)	Decelerating: 6(3%)	Steady Driving: 70(38%)
Never: 32(17%)	No Response: 0	

Q.16. How often did you look at the device when it was first installed in your car?

Never: 1(1%)	Rarely: 4(2%)	Sometimes: 26(14%)	Frequently: 137(74%)
No Response: 17(9%)			

Q.17. How often did you look at the device toward the end of the test?

Never: 9(5%)	Rarely: 33(18%)	Sometimes: 62(34%)	Frequently: 64(35%)
No Response: 17(9%)			

Q.18. In your opinion, what percentage of fuel can be saved through diligent use of this device?

None: 14(8%)	1-5%: 63(34%)	6-10%: 55(30%)	11-15%: 10(5%)
16-20%: 5(3%)	Over 20%: 0	No Response: 38(21%)	

Section B – Cont'd

Q.19. How do you feel that the device and its use influence driving safety?

Moderate Increase: 43(23%)	Great Increase: 7(4%)	No Affect: 96(52%)
Moderate Decrease: 20(11%)	Great Decrease: 1(1%)	No Response: 18(10%)

Q.22. What degree of effort was required to read the display?

Very Easy: 126(68%)	Moderately Easy: 35(19%)	Moderately Difficult: 6(3%)
Very Difficult: 1(1%)	No Response: 17(9%)	

Q.23. Has practice using the device decreased the effort required to use it?

No Change: 77(42%)	Somewhat Easier To Use: 48(26%)
Much Easier To Use: 36(19%)	No Response: 24(13%)

Section C

	Yes #(%)	No #(%)	No Response #(%)
Q. 1. Did the Training Course (TC) motivate you to drive your vehicle more fuel efficiently?	90(81)	21(19)	—
Q. 2. Did the TC motivate you to drive your *private* vehicle(s) more fuel efficiently?	88(79)	23(21)	—
Q. 3. If you stated yes on Questions 1 or 2, are you continuing to practice fuel conservation driving techniques?	93(84)	2(2)	16(14)
Q. 4. Did you tell other members of your family about some of the TC fuel conservation driving techniques?	91(82)	19(17)	1(1)
Q. 5. Did the TC cause you to consider the purchase of a vacuum gauge for your personal vehicle?	40(36)	68(61)	3(3)
Q. 6. Would you like to receive *more* information on fuel conservation driving techniques?	80(72)	28(25)	3(3)
Q. 7. Would you like to see the course expanded to all Nevada Test Site licensed driver employees?	87(78)	15(14)	9(8)

Q. 8. What is your current evaluation of the training course?

Poor: 5(5%) Fair: 16(14%) Good: 73(66%) Excellent: 16(14%) No Response: 1(1%)

Section C – Cont'd

	Yes #(%)	No #(%)	No Response #(%)
Q. 9. Have you installed a vacuum gauge on your own personal vehicle?	11(10)	99(89)	1(1)
Q.10. Would a well prepared movie have been as effective as the instructor conducted training course?	33(30)	74(67)	4(4)
Q.11. Did you feel handicapped because you did not have a device installed in your vehicle (Group 3 only)?	10(9)	41(37)	60(54)

Q.12. How could TC be improved?	Emphasize	Deemphasize	No Response
a. Classroom instruction	53(48)	12(11)	46(41)
b. Behind-the-Wheel instruction	84(76)	4(4)	23(21)
c. Visual aids	51(46)	13(12)	47(42)
d. Question and answer period	54(49)	13(12)	44(40)
e. Detailed information on vehicle functions	66(59)	8(7)	37(33)
f. Conservation movies	51(46)	15(14)	45(41)
g. Interaction among students	32(20)	19(17)	60(54)
h. Other	—	—	—

APPENDIX E

ADDITIONAL TEST DATA

APPENDIX E

ADDITIONAL TEST DATA

Tables E-1 and E-2 present the test results by test group and vehicle class for the highway and urban test segments, respectively. Tables E-3 and E-4 present comparisons of the test results by test vehicle age for the highway and urban segments, respectively.

Figures E-1 through E-6 present the comparison of Fuel Efficiency Ratio* versus fuel economy for the piston vacuum gauge groups for each of the vehicle size classes in each test segment. No general correlation between fuel economy and Fuel Efficiency Ratio was found to exist in the data.

* Fuel Efficiency Ratio (FER) is defined as the total number of low engine vacuum events divided by the number of engine starts. The piston vacuum gauge manufacturer claimed that there was a correlation between FER and fuel economy.

TABLE E-1

Highway Segment Comparison of Phase I and Phase II Results by Vehicle Type

Test Group	Compact				Intermediate				Pickup Truck			
	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ
1. Piston Vacuum Gauge	11	17.1	18.1	1.0	8	13.4	13.6	0.2	45	11.7	12.1	0.4
2. Control	10	16.3	16.7	0.4	8	14.0	14.1	0.1	45	11.5	11.7	0.2
3. Driver Training Course	10	16.1	16.1	0	10	14.2	14.6	0.4	48	12.0	12.5	0.5
4. Dial Gauge Plus Training	11	16.7	17.5	0.8	9	13.5	14.7	1.2	45	12.0	12.4	0.4
5. Dial Vacuum Gauge	11	16.4	17.0	0.6	7	13.7	14.2	0.5	48	11.7	12.2	0.5

Legend:

n = number of vehicles
1 = mean fuel economy during Phase I (mpg)
2 = mean fuel economy during Phase II (mpg)
Δ = difference in means between Phases I and II (mpg)

TABLE E-2

Urban Segment Comparison of Background to Test Results by Vehicle Type

Test Group	Compact				Intermediate				Pickup Truck			
	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ
1. Piston Vacuum Gauge	9	12.1	11.7	0.4	3	8.2	9.8	1.6	8	10.4	9.8	0.6
2. Control	12	11.4	11.6	0.2	6	9.7	10.7	1.0	10	9.5	10.0	0.5
3. Driver Training Course	13	10.8	11.8	1.0	5	8.6	9.5	0.9	9	9.7	10.2	0.5
4. Dial Gauge Plus Training	11	11.5	12.1	0.6	4	9.7	10.1	0.4	9	8.6	9.2	0.6
5. Dial Vacuum Gauge	12	11.4	12.1	0.7	2	—	11.5	—	10	10.5	10.8	0.3

Legend:

n = number of vehicles
1 = mean fuel economy during Phase I (mpg)
2 = mean fuel economy during Phase II (mpg)
Δ = difference in means between Phases I and II (mpg)

TABLE E-3

Comparison of Highway Segment Test Results by Vehicle Age

Group	1969				1970				1971				1972			
	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ
1. Piston Vacuum Gauge	n	13.2	13.8	0.6	3	14.2	15.2	1.0	7	13.4	13.6	0.2	3	13.4	13.4	0
2. Control	1	14.0	14.0	0	5	14.1	15.1	1.0	7	13.5	13.6	0.1	1	13.0	14.1	1.1
3. Driver Training Course	3	16.3	16.4	0.1	1	16.2	17.7	1.5	10	12.9	13.4	0.5	2	14.1	14.2	0.1
4. Dial Gauge Plus Training	2	16.3	15.3	−1.0	3	14.2	15.8	1.6	10	13.4	13.9	0.5	3	13.3	13.7	0.4
5. Dial Vacuum Gauge	1	15.7	14.4	−1.3	1	13.5	13.5	0	11	13.5	13.2	0.3	2	14.5	15.7	1.2

Legend:

n = number of vehicles
1 = mean fuel economy during Phase I (mpg)
2 = mean fuel economy during Phase II (mpg)
Δ = difference in means between Phases I and II (mpg)

TABLE E-3 (Continued)

Group	1969				1970				1971				1972			
	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ	n	1	2	Δ
1. Piston Vacuum Gauge	2	12.8	12.3	−.5	38	11.4	12.0	0.6	7	15.7	18.5	2.8	3	18.1	18.0	−0.1
2. Control	2	13.3	13.2	−.1	45	11.9	12.7	0.8	1	11.0	11.3	0.3	1	18.2	18.1	−0.1
3. Driver Training Course	1	11.9	12.8	0.8	48	12.3	12.9	0.6	2	16.0	17.4	1.4	1	17.6	17.1	−0.5
4. Dial Gauge Plus Training	1	11.3	12.7	1.4	42	12.2	13.2	1.0	3	15.4	17.3	1.9	1	18.5	17.4	−1.1
5. Dial Vacuum Gauge	2	12.5	12.7	0.2	42	11.8	12.8	1.0	6	15.4	17.3	1.9	1	19.0	17.7	−1.3

Legend:

n = number of vehicles
1 = mean fuel economy during Phase I (mpg)
2 = mean fuel economy during Phase II (mpg)
Δ = difference in means between Phases I and II (mpg)

TABLE E-4

Comparison of Urban Segment Test Results by Vehicle Age

Group	1971				1972				1973			
	n	b	t	Δ	n	b	t	Δ	n	b	t	Δ
1. Piston Vacuum Gauge	1	10.8	11.1	0.3	1	8.2	9.8	1.6	5	11.4	10.8	−0.5
2. Control	0	—	—	—	4	9.9	10.9	1.0	5	10.3	10.4	0.1
3. Driver Training Course	1	11.8	11.8	0	2	7.8	7.6	−0.2	3	11.1	9.8	−0.3
4. Dial Gauge Plus Training	0	—	—	—	3	8.1	8.2	0.1	4	11.3	10.8	−0.5
5. Dial Vacuum Gauge	1	11.7	9.7	−0.2	2	9.7	11.2	1.5	2	12.7	12.8	0.1

Legend:

n = number of vehicles
b = mean fuel economy during background period (mpg)
t = mean fuel economy during test period (mpg)
Δ = difference in means between background and test (mpg)

TABLE E-4 (Continued)

Group	1974				1975			
	n	b	t	Δ	n	b	t	Δ
1. Piston Vacuum Gauge	8	11.2	10.3	−0.9	5	11.4	11.3	−0.1
2. Control	13	10.7	11.0	0.3	65	10.3	10.8	0.5
3. Driver Training Course	15	10.0	11.3	1.2	6	10.9	11.2	0.3
4. Dial Gauge Plus Training	8	9.1	9.8	0.7	9	11.4	12.2	0.8
5. Dial Vacuum Gauge	13	10.6	11.4	0.8	6	11.4	11.7	0.3

Legend:

n = number of vehicles
b = mean fuel economy during background period (mpg)
t = mean fuel economy during test period (mpg)
Δ = difference in means between background and test (mpg)

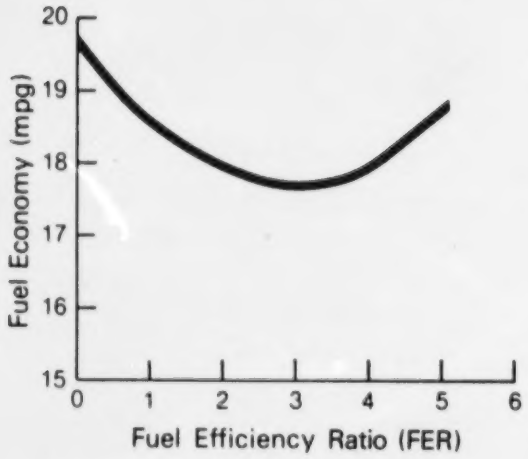


Figure E-1

Fuel Economy vs Fuel Efficiency Ratio*, Compacts, Highway Test Segment

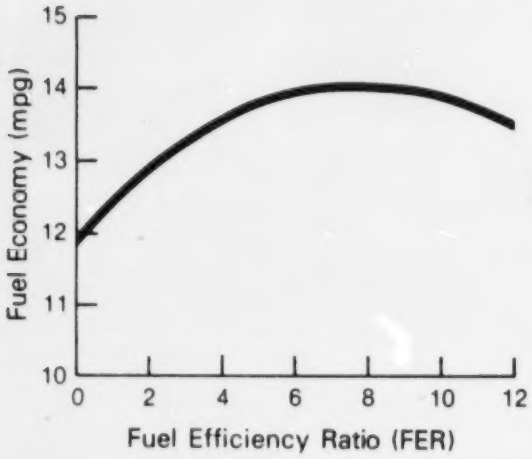


Figure E-2

Fuel Economy vs Fuel Efficiency Ratio* Intermediates, Highway Test Segment

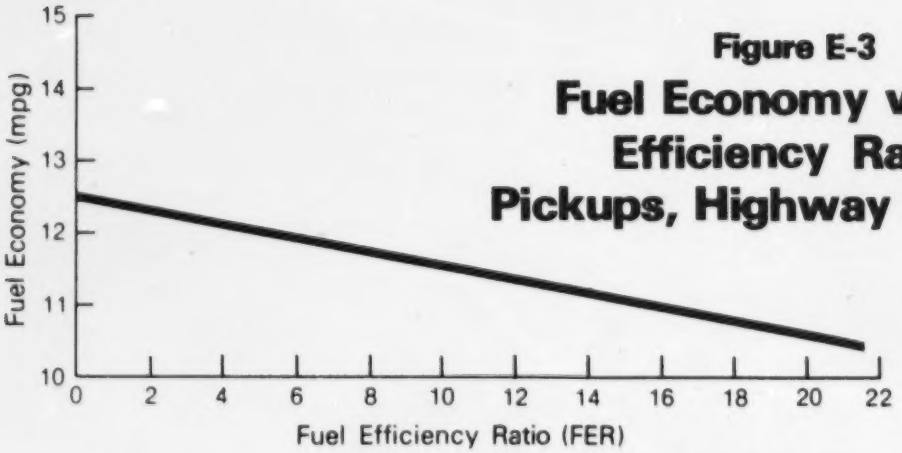


Figure E-3

Fuel Economy vs Fuel Efficiency Ratio* Pickups, Highway Segment

$$*\text{Fuel Efficiency Ratio} = \frac{\#\text{ of Low Vacuum Events}}{\#\text{ of Engine Starts}}$$

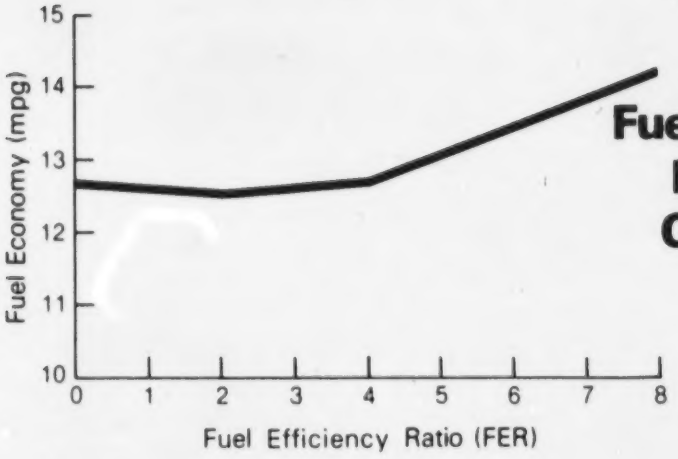


Figure E-4

Fuel Economy vs Fuel Efficiency Ratio* Compacts, Urban Segment

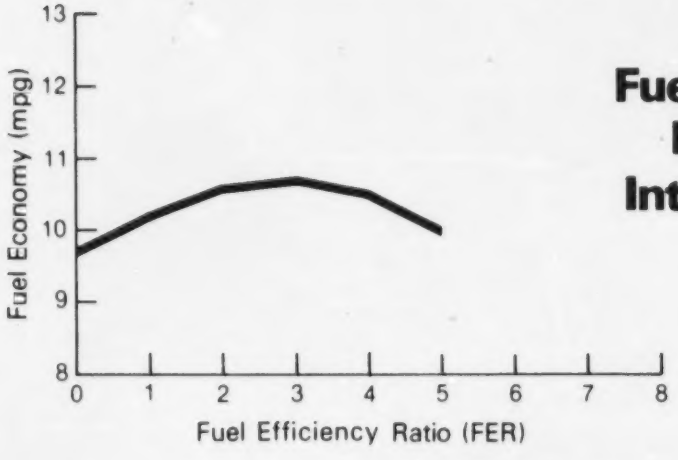


Figure E-5

Fuel Economy vs Fuel Efficiency Ratio* Intermediates, Urban Segment

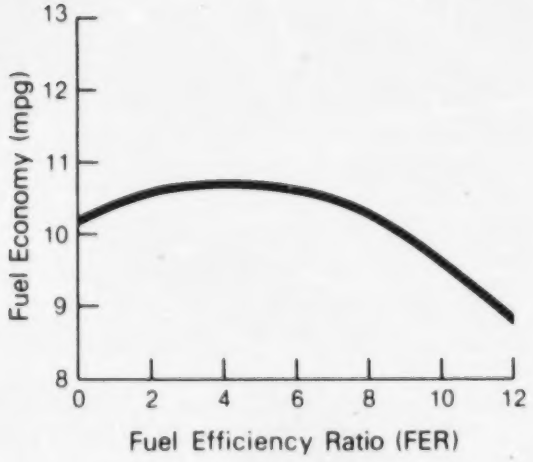


Figure E-6

Fuel Economy vs Fuel Efficiency Ratio* Pickups, Urban Segment

$$\text{*Fuel Efficiency Ratio} = \frac{\text{\# of Low Vacuum Events}}{\text{\# of Engine Starts}}$$

APPENDIX F

AVAILABLE DATA FILES

APPENDIX F

AVAILABLE DATA FILES

The following data files are available on magnetic tape at the Nevada Operations Office, Las Vegas Nevada:

1. Unedited Data (By Vehicle)
   - vehicle identification number
   - monthly fuel economy
   - mean mpg, Phase I average monthly fuel economy
   - standard deviation of monthly fuel economy, Phase I
   - vehicle year
   - vehicle make
   - vehicle model
   - transmission type (automatic/manual)
   - air conditioning (yes/no)
   - vehicle type (compact, intermediate, pick-up)
   - test group
2. Edited Data (By Month)
   - test group
   - vehicle type
   - vehicle identification number
   - date of record
   - number of days since vehicle entry into test
   - fuel economy each month
3. Edited Data (By Fill-up)
   - test group
   - vehicle type
   - vehicle identification number

- date of record
- number of days since entry into test
- fuel economy - each fill-up (mpg.)

4. Edited Vehicle Log Data
   - vehicle identification number
   - fuel delivered (to 0.1 gallon)
   - odometer reading (miles)
   - date of fill-up
   - number of days since entry into test

5. VacTach Data (Two files raw and edited data)
   - vehicle identification number
   - fuel delivered (to 0.1 gallon)
   - odometer reading (miles)
   - date of fill-up
   - fueling station identification number
   - driver's initials
   - VacTach count of starts
   - VacTach count of violations

6. Vehicle Characteristics
   - identification number
   - year
   - make
   - model
   - options
   - date entered Phase I
   - date entered Phase II
   - odometer reading at start of test

- date removed from test (if appropriate)
- date primary driver was trained (Groups 3 and 4 only)

7. Air Temperature at Mercury, Nevada
   - date
   - mean temperature
   - maximum temperature
   - minimum temperature
8. Unedited Test Vehicle Log Data (From fueling station)
   - vehicle identification number
   - fuel delivered (to 0.1 gallon)
   - odometer reading
   - date
   - fueling station identification number

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